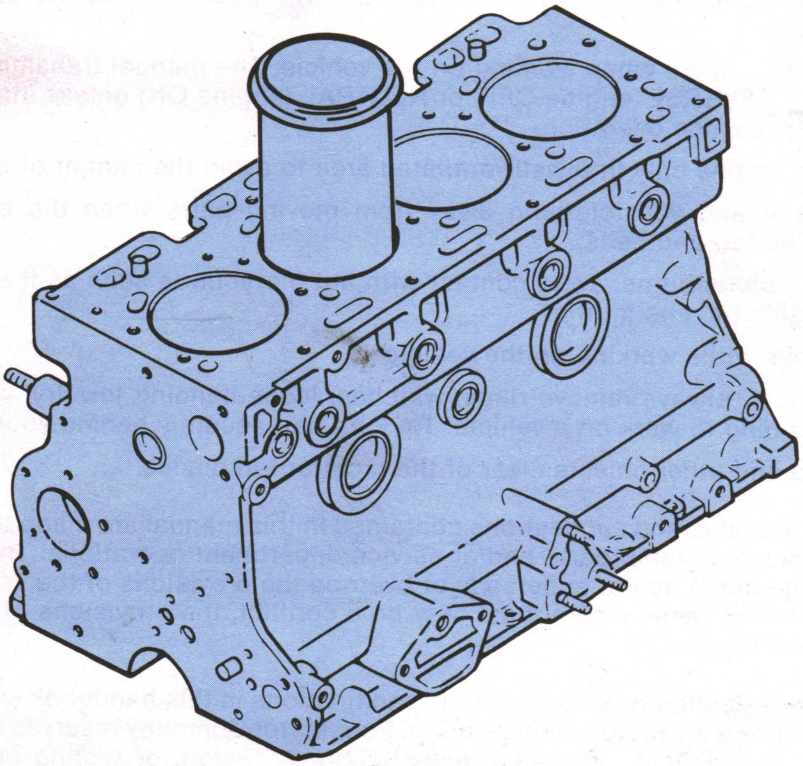
Bill Curtis 6-6-99

Overhauling Diesel Engines



Ford Parts and Service Division
Training and Publications Department

IMPORTANT SAFETY NOTICE

Appropriate service methods and proper repair procedures are essential for the safe, reliable operation of all motor vehicles, as well as for the personal safety of the individual doing the work. This manual provides general directions for accomplishing service and repair work with tested, effective techniques. Following them will help assure reliability.

There are numerous variations in procedures, techniques, tools, and parts for servicing vehicles, as well as in the skill of the individual doing the work. This manual cannot possibly anticipate all such variations and provide advice or cautions as to each. Accordingly, anyone who departs from instructions provided in this manual must first establish that he compromises neither his personal safety nor the vehicle integrity by his choice of methods, tools, or parts.

As you read through the procedures, you will come across **NOTES, CAUTIONS,** and **WARNINGS.** Each one is there for a specific purpose. **NOTES** give you added information that will help you to complete a particular procedure. **CAUTIONS** are given to prevent you from making an error that could damage the vehicle. **WARNINGS** remind you to be especially careful in those areas where carelessness can cause personal injury. The following list contains some general **WARNINGS** that you should follow when you work on a vehicle.

- Always wear safety glasses for eye protection.
- Use safety stands whenever a procedure requires you to be under the vehicle.
- Be sure that the ignition switch is always in the OFF position, unless otherwise required by the procedure.
- Set the parking brake when working on the vehicle. The manual transmission shifter lever should be in REVERSE (engine OFF) or NEUTRAL (engine ON) unless instructed otherwise for a specific service operation.
- Operate the engine only in a well-ventilated area to avoid the danger of carbon monoxide.
- Keep yourself and your clothing away from moving parts when the engine is running, especially the fan and belts.
- To prevent serious burns, avoid contact with hot metal parts such as the radiator, exhaust manifold, tail pipe, and muffler.
- Do not smoke while working on the vehicle.
- To avoid injury, always remove rings, watches, loose hanging jewelry, and loose clothing before beginning to work on a vehicle. Tie long hair securely behind your head.
- Keep hands and other objects clear of the radiator fan blades.

The recommendations and suggestions contained in this manual are made to assist the dealer in improving his dealership parts and/or service department operations. These recommendations and suggestions do not supersede or override the provisions of the Warranty and Policy Manual, and in any cases where there may be a conflict, the provisions of the Warranty and Policy Manual shall govern.

The descriptions, testing procedures, and specifications in this handbook were in effect at the time the handbook was approved for printing. Ford Motor Company reserves the right to discontinue models at any time, or change specifications, design, or testing procedures without notice and without incurring obligation. Any reference to brand names in this manual is intended merely as an example of the types of tools, lubricants, materials, etc. recommended for use. Equivalents, if available, may be used. The right is reserved to make changes at any time without notice.

Copyright 1984, Ford Motor Company

TABLE OF CONTENTS

OBJECTIVES iii

INTRODUCTION 1

DIAGNOSIS 1

- Preliminary Considerations 1
- Sensory Diagnosis 2
  - Feel 2
  - Sight 2
  - Exhaust Smoke Diagnosis 3
  - Odor 6
  - Sound 6
- Test Equipment Used in Engine Diagnosis 7
  - Compression Tester 7
  - Oil Pressure Gauge 7
  - Cooling System Pressure Tester 8
  - Cylinder Leak Tester 8
  - Crankcase Pressure Tester 8
- Performing Diagnostic Tests on Diesel Engines 8
  - Checking Oil Pressure 8
  - Crankcase Pressure Check 8
  - Compression Test 9
  - Cylinder Leak Test 11
  - Oil Leak Diagnosis 11

CLEANING AND INSPECTION 12

- Engine Cleaning 12

ENGINE DISASSEMBLY TECHNIQUES 12

- Preoverhaul Considerations 12
- Timing Belt Removal 13
- Fuel Injection Pump Removal 14
- Cylinder Head Removal 14
- Short Block Disassembly 14
  - Piston Cooling Jets 15
  - Bearing Cap Removal 15
  - Piston Removal 15
  - Component Cleaning 16

CYLINDER HEAD INSPECTION AND SERVICE 16

- Cylinder Head and Valve Inspection 17
  - Valve Seat Inspection and Service 18
  - Valve Inspection and Service 20
  - Checking Valve Face and Valve Seat Contact 21

TABLE OF CONTENTS (Cont'd)

Component Inspection and Service 21
  Valve Springs 21
  Rocker Arms 22
  Push Rods 22
  Lifters 22
Camshaft Inspection and Service 22
  Camshaft Bearings 23

SHORT BLOCK INSPECTION AND SERVICE 24
Cylinder Block Inspection and Service 24
  Cylinder Wall Refinishing 25
  Cylinder Liners 26
Crankshaft Inspection and Service 27
Connecting Rod Inspection and Service 28
Main and Rod Bearing Inspection and Service 28
  Choosing Bearings 29
  Installing Bearings 29
  Checking Bearing Clearance 30
Gear Train and Timing Component Inspection and Service 30
Piston Inspection and Service 31
  Installing Piston Rings 32
  Piston Pins 32

DIESEL ENGINE ASSEMBLY 32
Assembling the Short Block 32
  Piston Cooling Jet Installation 33
  Crankshaft Installation 34
  Rod Installation 34
  Gasket and Seal Installation 34
Cylinder Head Installation 34
  Head Gasket Installation 34
  Tightening the Cylinder Head 35
  Finishing Assembly 35
Choosing Engine Oil 35

OBJECTIVES

UPON COMPLETION OF THIS MANUAL, YOU SHOULD BE ABLE TO CORRECTLY:

- Differentiate between symptoms that are caused by problems with the engine and those that are caused by problems in the fuel and/or electrical system.
- Use the proper tools and diagnostic techniques to determine engine problems.
- Perform a compression test using a diesel compression tester and interpret the results.
- Perform a cylinder leak test and interpret the results.
- Perform a crankcase pressure test and interpret the results.
- Check engine oil pressure and interpret the results.
- Follow shop manual procedures when disassembling, checking and assembling a diesel engine.
- Use the measuring tools outlined in the shop manual and in this reference manual.
    - — Micrometer
    - — Feeler gauge
    - — Plastigage
    - — Bore gauge
    - — Telescoping gauge
    - — Dial indicator
    - — Hole gauge
    - — Scale

NOTE: The problems specified in this manual often require a major or minor overhaul.

INTRODUCTION

This Reference Manual, "**Overhauling Diesel Engines,**" is the third in a series covering the general information that is common to most diesel engines. The two prior Reference Manuals are:

- **Basic Diesel Principles**
- **Diesel Fuel and Electrical System Diagnosis and Repair**

In this manual the specialized service procedures for overhauling diesel engines will be covered along with tools, tool usage, diagnostic techniques, and other important information. Technicians, who are not familiar with the operating characteristics of diesel engines, are encouraged to review the preceding Reference Manuals in this series before reading this one.

Essentially, the purpose of this manual is to familiarize Ford Service Technicians with the information necessary for proper diesel engine overhaul. Although many of the procedures are similar to those **sometimes** performed on gasoline engines, the procedures are necessary to follow on a diesel engine. This is due to the precise tolerances found within the engine and its operating characteristics. A good comparison would be to state that the care that goes into rebuilding a diesel engine must be to the same degree one would put into rebuilding a gasoline powered racing engine. Tolerances are critical; valve work must be exact; and cleanliness must be maintained throughout the entire overhaul.

Diesel engines are different from gasoline engines since they are meant to be rebuilt after performing long periods of service. Actually, diesels can often be rebuilt several times before their service life is over, with the lifetime of each rebuild equal or nearly equal to that of the original engine if the overhaul is done correctly.

The material presented in this manual does not cover a specific engine, and is to be used only as a general guide. For this reason it is important to always use the proper service publication when actually performing an overhaul. Use this manual to become familiar with the techniques of a correct diesel engine rebuild.

Included with this manual, as with the others in this series, is a videodisc entitled "Overhauling Diesel Engines." If possible, always view the videodisc before reading this manual.

DIAGNOSIS

PRELIMINARY CONSIDERATIONS

To diagnose a potential rebuild of a diesel, a technician must check all possible problem areas. This applies most specifically to the diesel fuel, electrical, and air induction systems. Remember, problems such as excessive knock, smoke, poor mileage, hard starting, missing, power loss, and others can also be attributed to these systems.

Use the charts available in the Diesel Fuel and Electrical System Diagnosis Reference Manual to help locate a problem area and to determine how to correct it. Also, use the proper service publications that contain the diagnostic sequence for the particular engine or vehicle being worked on. Following the manufacturer's recommended sequence for diagnosing a diesel engine will help to ensure that all problems are found. The last thing that anyone wants to happen is to repair something that did not need to be repaired, or to miss finding all the contributing factors to a particular problem and have it recur. In addition to following the diagnostic sequence, make checks to ensure that the following non-engine factors (which are not always taken into condsideration on the diagnostic sequences) are either checked or noted before making a diagnostic decision:

- Speedometer error
- Transmission
- Tires and inflation pressure
  - — Snow tires, radials included, can reduce mileage as much as 2 mpg.
- Weather
  - — Cold increases the viscosity of lubricants in the power train (especially wheel bearing grease). This plus adverse driving conditions requires more power and decreases mileage.

DIAGNOSIS

SENSORY DIAGNOSIS

Diagnosis always begins by sensing that something is not correct. It may not "feel" right; something does not "look" right; there is a different "smell"; or maybe the engine does not "sound" the way it should. These are diagnostic clues. If interpreted properly, these clues can point in the direction of a possible problem area, and with the proper test equipment can be verified. Remember, most customers will describe their vehicle's problem in this way, so be aware of them to help in diagnosis. Let's take a closer look at sensory diagnosis on a diesel.

Feel

The feel of a diesel-powered vehicle is usually not all that different than the conventional gasoline-powered models. Generally, diesel engines are somewhat sluggish on acceleration and will not be as "quick" as a gasoline-powered model with a comparable sized engine. There is nothing odd about this; it's just a characteristic of the diesel. Although the diesel is not as quick as a gasoline-powered model, it usually is not as affected by load as much as a gasoline engine. This will be evident when the vehicle is carrying cargo or is traveling on an upgrade.

When related to engine speed, the shift points on a diesel are different from gasoline engines. Most diesels do not operate in an rpm range that is as high as the gasoline engine. So obviously, the engine will, in most situations, be shifted at a lower rpm that will give it a different feel.

A customer may notice that the engine vibrates more than a gasoline engine, especially at idle. This won't usually be noticed in the vehicle because of the sound and vibration packages installed with the diesel engine; however, it may be noticed on the outside of the vehicle. This vibration is another characteristic of the diesel engine and is a by-product of extremely high compression ratio and compression ignition. The technician should be familiar with the normal amount of vibration. If a vehicle does have excessive vibration, the technician should take it into consideration.

Sight

Visual detection of possible problem symptoms is extremely important. A simple visual inspection of the entire vehicle is necessary before beginning any job. Symptoms to look for under the hood include:

- Coolant leaks
- Oil leaks
- Loose or binding components
- Fuel leaks
- Exhaust system damage that could restrict exhaust flow
- Anything that looks out of the ordinary

Leaks of any type will cause problems and should be corrected immediately. Oil leaks from a diesel are like those from a gasoline engine—a nuisance. They cause oil loss, attract dirt, and create a grimy buildup that helps to hold heat in the engine and overworks the cooling system.

Coolant leaks can be very detrimental to engine life and can cause severe engine damage. When coolant is lost, it reduces the efficiency of the cooling system. The coolant can leak out when the system is pressurized and air can leak in when the system cools down. Air that leaks into a cooling system usually gathers at the highest point (the top of the radiator). However, sometimes air can gather in the pockets around the combustion chamber in the cylinder head or along the cylinder walls. These pockets of air can cause inadequate cooling and are often called "hot spots." The difference in the temperature between the "hot spot" and the other areas of the head or cylinder block can cause cracking or warping, especially in the aluminum cylinder heads used on many of the modern automotive diesels.

Some diesels are equipped with a coolant expansion tank (Fig. 1). This tank is responsible for removing air that may be in the coolant.

NOTE: Notice in Figure 1 that the location of the coolant expansion tank in relation to the other cooling system components is higher. This is because air tends to gather at the highest point in the cooling system.

Diesel engines produce a large amount of heat from burning diesel fuel, and must be adequately cooled. Watch the condition of all the cooling system components, and be sure there are no air leaks.

Fuel leaks can cause many problems that could be attributed to the engine. Be sure there are no fuel leaks (or air leaks) when an engine problem is suspected. Use the diagnostic methods explained in the Diesel Fuel and Electrical System Diagnosis Manual or in the proper shop manual or service publication.

WARNING: Be extremely cautious around high pressure fuel leaks. Leaks from this side of the fuel system are under enough pressure to pierce the skin which may cause blood poisoning. If struck by high pressure fuel, seek medical help immediately.

DIAGNOSIS

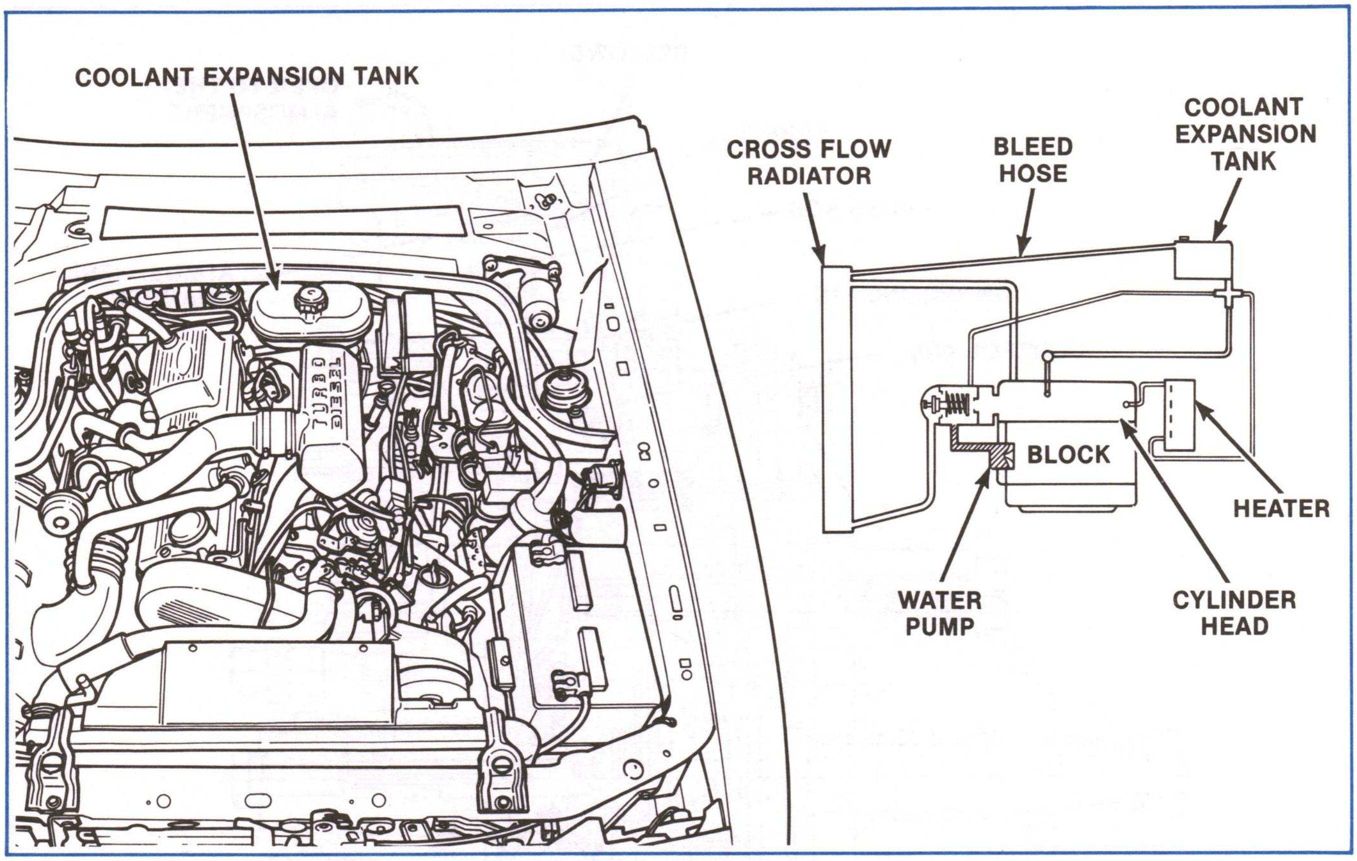


Figure 1. Cooling System with Expansion Tank

When working under the hood or beneath the vehicle be sure that there are no damaged, loose or binding components which may cause noise or cause the vehicle to perform below standards. Also, look for wiring or vacuum hoses that might be bound. Because of the use of vacuum pump and glow plugs, anything that might bind the wiring or hoses could cause trouble.

Exhaust Smoke Diagnosis

Looking at the exhaust smoke coming from the tailpipe is one of the most important visual diagnostic inspections. The color, consistency, and odor of the exhaust can indicate a lot to the experienced diesel technician. Generally, there are three types of smoke.

White Smoke

Normally, white smoke will appear when the engine is first started. This is caused by fuel condensing on the cold cylinder walls and not burning. The white smoke should stop as the engine warms up. Continuing white smoke is a sign that there is a problem:

- A stuck thermostat prevents the engine from reaching operating temperature.
- Water in the combustion chamber caused by a leaking head gasket, cracked head, or cylinder.
- Low compression caused by a blown head gasket, poor valve sealing, or poor piston ring sealing.

Black or Dark Gray Smoke

The appearance of black or dark gray smoke is probably the most common complaint. This type of exhaust smoke is normally caused by an over-rich mixture of fuel and air. A certain amount of black smoke is normal in some operating conditions, such as heavy acceleration or driving under a load. Also, altitude can also have an effect on the amount of dark smoke coming from the tailpipe. The thin air at higher elevations causes the actual air/fuel ratio to be richer unless the fuel injection pump contains an altitude compensation device (Fig. 2) to lean the mixture.

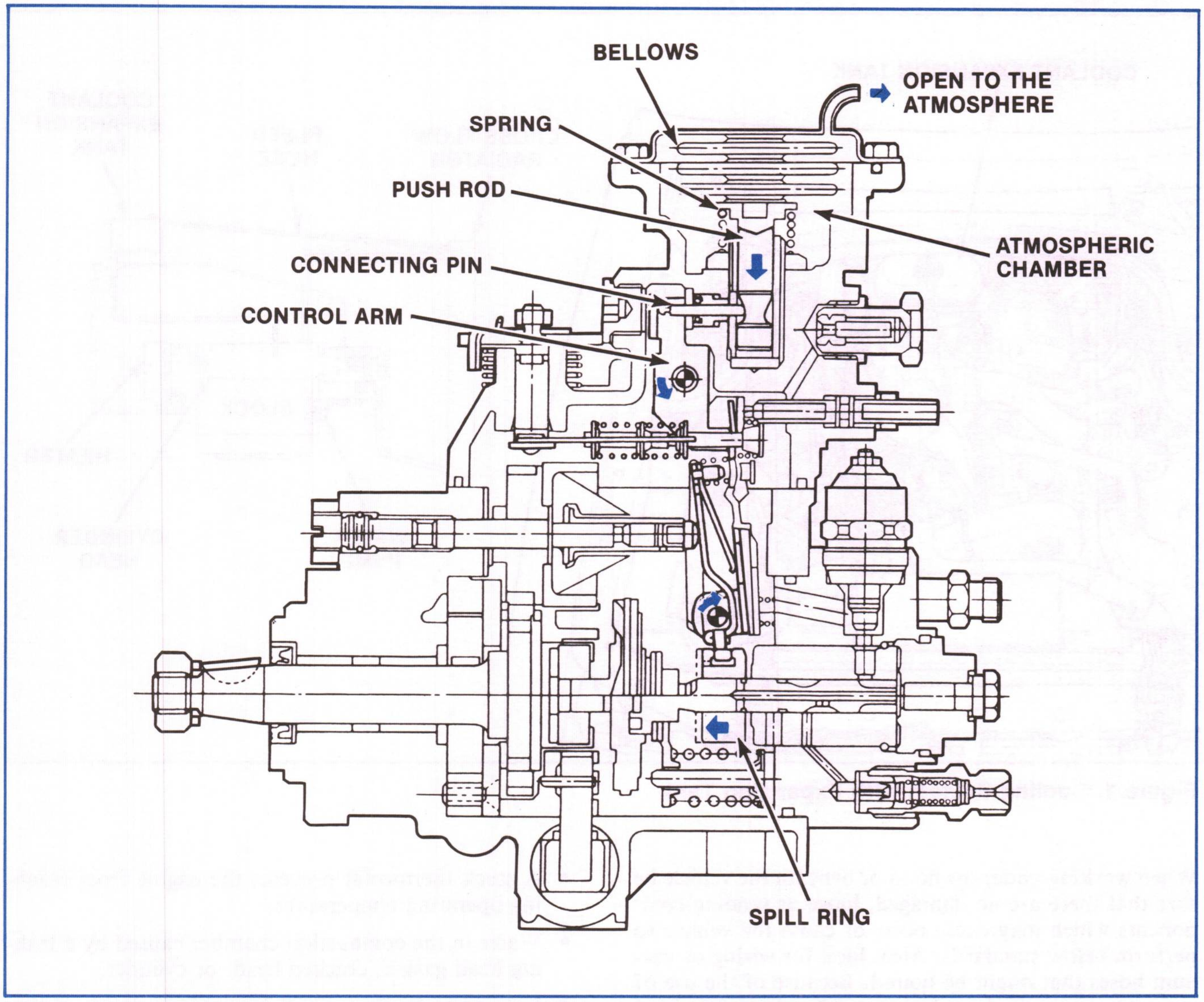


Figure 2. Fuel Injection Pump with Altitude Compensation Device

NOTE: Not all fuel injection pumps contain altitude compensation devices. Check the shop manual or other service publication to find out if it is so equipped. Remember, diesel engines that are not equipped with altitude compensation components will smoke excessively at high altitudes which is completely normal. If the diesel engine is equipped with these components and it smokes excessively, there may be a malfunction.

There are actually many possible malfunctions that could cause a symptom of excessive black or dark gray smoke. Use the chart on Page 5 to assist in determining the actual problem(s).

Blue or Bluish White Smoke

Blue smoke indicates that oil is being burned in the combustion chambers. This is an indication that there is an engine problem. It may be something minor such as valve seals, or it could be as major as worn piston rings or worn cylinders. In a situation where blue smoke is present, the same diagnostic routines that work on gasoline engines can also apply to diesels.

The following chart should be helpful in determining the cause of smoke from diesel engines.

DIAGNOSIS

Black or Dark Gray Smoke

SYMPTOM	PROBABLE CAUSE	ACTION TO TAKE	COMMENTS
Smoke at full load, particularly at high and medium speeds; engine quieter than normal	Pump timing retarded	Check and adjust timing to specifications	Pump timing changes only if moved intentionally, or if mountings are not properly tightened
Smoke at full load, particularly at low and medium speeds; engine noisier than normal	Pump timing advanced	Check and adjust timing to specifications	
Smoke at full load, particularly at high and medium speeds, probably with loss of power	Injection nozzle(s) discharge hole fully or partly blocked	Clean or replace injection nozzles as required	
Smoke at full load, at higher speeds only	Air cleaner filter restricted	Replace air cleaner filter	Replace filter at scheduled intervals or more often under severe service conditions
Intermittent or puffy smoke, sometimes with white or bluish tinge, usually accompanied by engine knocking	Injector nozzle valve sticks open intermittently	Check injection nozzles for sticking valve, broken spring, or very low opening pressure; also check for cross-threading in head	May be caused by dirt or water in fuel; injection nozzle should screw into head freely and must not be over-tightened
Smoke at all speeds at high loads, mostly at low and medium speeds and probably accompanied by hard starting	Loss of cylinder compression because of stuck rings, bore wear, burning, sticking valves, or incorrect valve setting	Engine requires overhaul if wear indications are present; check valve setting Check compression	May be caused by improper crankcase oil or incorrect valve clearance
Smoke at full load, mostly at medium and high speeds, and probably accompanied by low power	Injection fuel lines clogged or restricted because of damage	Check injection fuel lines; clean or replace as required	Fuel lines must be clear and unrestricted

Blue, Bluish Gray or Grayish White Smoke

SYMPTOM	PROBABLE CAUSE	ACTION TO TAKE	COMMENTS
Blue or whitish smoke particularly when cold, and at high speeds and light load, but reducing or changing to black when hot and at full load, with loss of power at least at high speeds	Pump timing retarded	Check and adjust pump timing	Some engines show this symptom for less retard than gives rise to black smoke, but usually substantial retard is required to produce blue smoke when running hot and under load
Blue or whitish smoke when cold, particularly at light loads but persisting when hot, probably accompanied by knocking	Injection nozzle valve stuck open or nozzle tip damaged and leaking	Examine nozzle for valve stuck open or nozzle tip damage	
Blue smoke at all speeds and loads, hot or cold	Engine oil being passed by piston rings because of sticking rings or bore wear	Engine reconditioning as required	May be caused by improper crankcase oil; will be associated with high oil consumption
Blue smoke, particularly when accelerating from period of idling, tending to clear with running	Engine oil being passed by worn inlet valve guides, or valve stem umbrella seals worn or missing	Engine reconditioning as required	
Light blue smoke at high-speed light loads, or running downhill, usually accompanied by sharp odor	Engine running cold; thermostat stuck open	Replace thermostat	Low temperatures also increase bore wear

DIAGNOSIS

Odor

Diesel engines have a very distinct odor because of the type of fuel used and the method of combustion. The odor intensity can vary due to the engine temperature, amount of fuel being injected, load on the engine, etc. There is no correction for the odor; however, a pungent odor may indicate there is a malfunction.

Generally, the types of odors that indicate other problems such as coolant leaks, slipping belts, and melting insulation on wiring, etc., will be the same on diesels as on gasoline engines. Watch closely for the odor of gasoline in the fuel. Sometimes, the driver or a careless service station attendant will put gasoline into the tank. If this should happen, drain the fuel tank immediately. Gasoline flowing through the fuel system can cause severe damage to the fuel injection pump and fuel injectors, possibly causing them to seize. Damage to the fuel system or engine caused by gasoline in the fuel is not covered by warranty.

NOTE: Some manufacturers in the past have recommended that gasoline be added to diesel fuel during the winter to thin the diesel fuel. This is not recommended by Ford Motor Company and will void the warranty. Use only the recommended fuel in diesel engines.

Sound

Diesels have their very own sound regardless of whether it is an automotive type or one used to power over the road trucks or construction equipment. The type of noise produced by a diesel is caused by the method of igniting the fuel, which is"compression" ignition. Fuel is ignited by being injected under extremely high pressure into hot, compressed air. The timing of the injection is extremely important, not only to the performance of the engine, but also to the amount of combustion noise it produces. **If for some reason, the burning fuel reaches maximum pressure before the piston reaches top-dead-center, a severe knock will result. A knock that sounds like a rod or main bearing going out.**

This type of severe combustion knock can occur for many reasons and is examined in greater detail in the Diesel Fuel and Electrical System Diagnosis Reference Manual and videodisc. It is important to thoroughly examine the possibility that a knock is caused by improper combustion instead of a failed component inside the engine.

In most cases, if a component fails in a diesel, the noise will be similar to a component in a gasoline engine. A bad wrist pin will still sound like a bad wrist pin and a bad lifter will still sound like a bad lifter. The technician should use good judgement in determing a malfunction and check out all possibilities.

To locate a noise and determine if it is fuel related or engine related, the following procedure will have to be followed:

Loosen the high pressure fuel inlet on each injector one at a time (Fig. 3) using a fuel line wrench or equivalent tool.

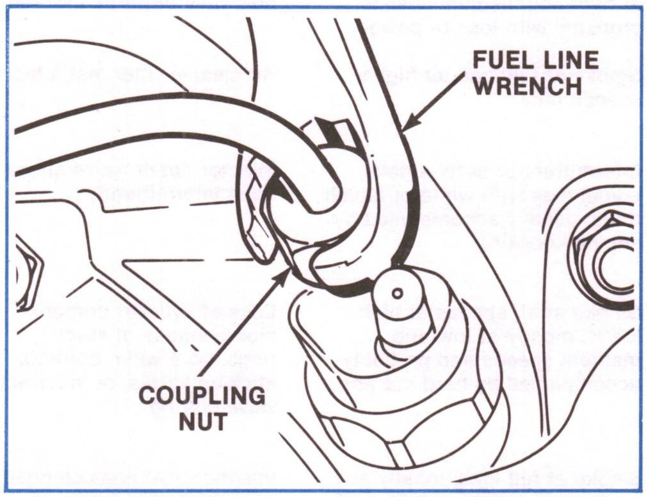


Figure 3. Loosening a High Pressure Fuel Line

When the sound disappears as a fuel line is loosened, the problem cylinder has been found.

NOTE: This is similar to pulling plug wires on a gas engine to determine where a knock is located.

Remove the fuel injector from that cylinder and test it to ensure that it is operating properly using the Rotunda Fuel Injection Nozzle Tester (Fig. 4).

NOTE: The procedures for checking fuel injection nozzles are located in the shop manual, the Diesel Fuel and Electrical System Diagnosis and Repair Manual, and other service publications.

If the fuel injector is operating correctly, there is probably a problem in the engine; however, be sure that all of the other possibilities like fuel quality, air in the system, cetane rating, pump timing, fuel injection pump, etc., have been checked before working on the engine.

If the fuel injection nozzle is bad, replace or rebuild it according to the manufacturer's recommended instructions. Then, retest to see if the noise is still there.

DIAGNOSIS

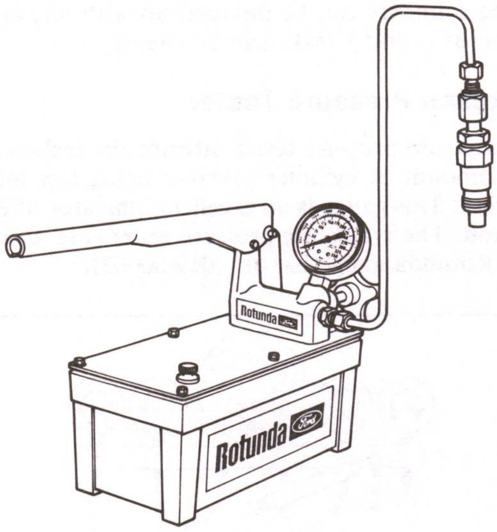


Figure 4. Rotunda Fuel Injection Nozzle Tester (014-00300 or equivalent)

TEST EQUIPMENT USED IN ENGINE DIAGNOSIS

Use only the test equipment for diesel engines to find and verify problems.

The following tools are commonly used in diagnosing diesel engines. In addition to a description of each tool, there will also be an explanation of how each tool is used later in the Reference Manual.

Compression Tester (019-00001)

The compression tester (Fig. 5) used on diesel engines is a special one that reads to 1000 psi (7000 kPa). Diesels have an extremely high compression ratio (often over 20:1) that produce pressures beyond the capacity of conventional compression testers.

NOTE: Do not attempt to use a conventional compression tester on a diesel engine. The high pressures produced by the diesel engine may damage a conventional compression tester.

Oil Pressure Gauge

Use an accurate oil pressure gauge to assist in diagnosing possible engine problems. An oil pressure gauge is on the Rotunda gauge bar (019-00002) (Fig. 6) that reads pressures from 0–160 psi.

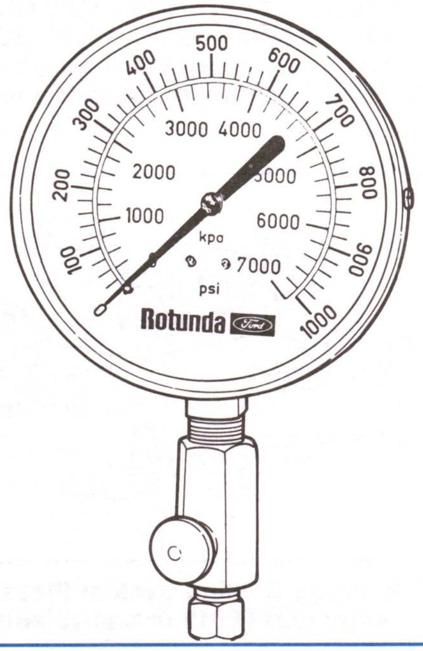


Figure 5. Rotunda Diesel Compression Tester (019-00001 or equivalent)

NOTE: The fitting that goes on the engine will vary between the different diesel engines. Be sure the correct one is used to prevent cross threading or other problems.

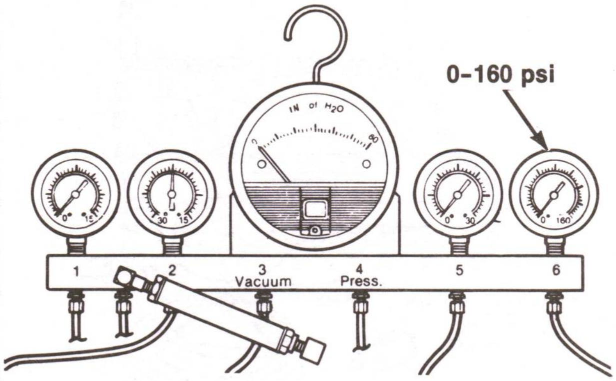


Figure 6. Rotunda Gauge Bar (019-00002 or equivalent)

Cooling System Pressure Tester (021-00012)

The cooling system pressure tester (021-00012) (Fig. 7) helps to locate possible cooling system leaks. These leaks can cause severe engine problems by allowing coolant to escape from the cooling system or allow air intake.

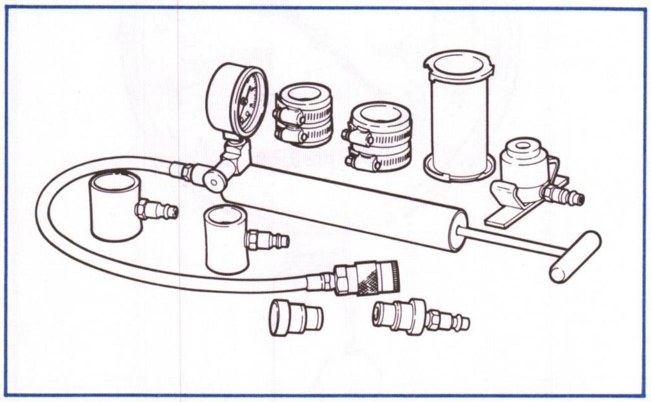


Figure 7. Rotunda Cooling System Pressure Tester (021-00012 or equivalent)

NOTE: Some diesel cooling systems require a special adapter to pressure test. Check with the shop manual.

Cylinder Leak Tester (019-00005)

A cylinder leak tester (Fig. 8) can determine the percentage a cylinder leaks; however, it is not necessary. It is necessary to have a hose with the proper adapters so that the cylinders can be pumped up with air, and the location of cylinder leaks can be found.

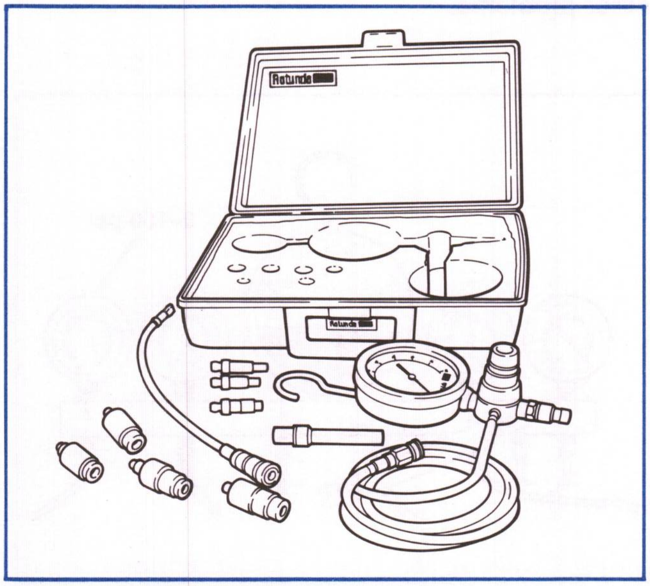


Figure 8. Cylinder Leak Tester and Hose (019-00005 or equivalent)

Crankcase Pressure Tester

The crankcase pressure tester informs the technician as to the amount of cylinder pressure being lost into the crankcase. This gauge is an excellent indicator of engine condition. The crankcase pressure tester (Fig. 9) is part of the Rotunda gauge bar set (019-00002).

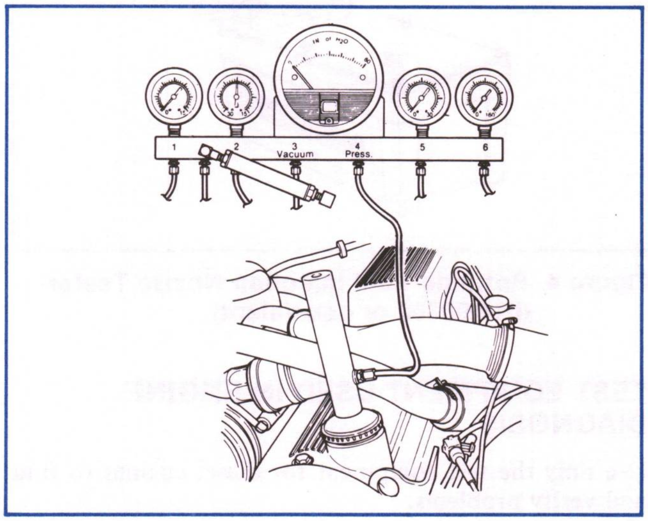


Figure 9. Crankcase Pressure Tester

PERFORMING DIAGNOSTIC TESTS ON DIESEL ENGINES

Checking Oil Pressure

Oil pressure can indicate a lot about the condition of an engine. Low oil pressure can be a quick indicator of problems with the oil pump, oil pickup, or possibly the bearings. Before performing the oil pressure test, be sure that there is an adequate amount of oil in the oil pan.

Crankcase Pressure Check

The crankcase pressure check gives information about the general condition of the engine. It measures the amount of blow-by past the piston rings. If the amount of blow-by is excessive, there is obviously a problem with the engine. Keep in mind that this test has to be performed at a certain rpm that will vary between the different diesel engines. Failing to follow the correct procedures for a particular engine may result in drawing incorrect conclusions from the readings. The correct procedures for checking an engine are found in the shop manual and in other Ford service publications.

Compression Test

The methods for compression testing will vary among diesel engines since some engines are checked with the engine warm while other engines are checked cold. Look in the shop manual or other service publication to see if the engine should be warmed up or not. Following are the general instructions for checking compression on a diesel engine.

1. Disconnect and remove all of the glow plugs from the engine.
2. Disconnect the glow plug harness (Fig. 10) or cover each glow plug connector with a piece of rubber hose to prevent it from grounding.

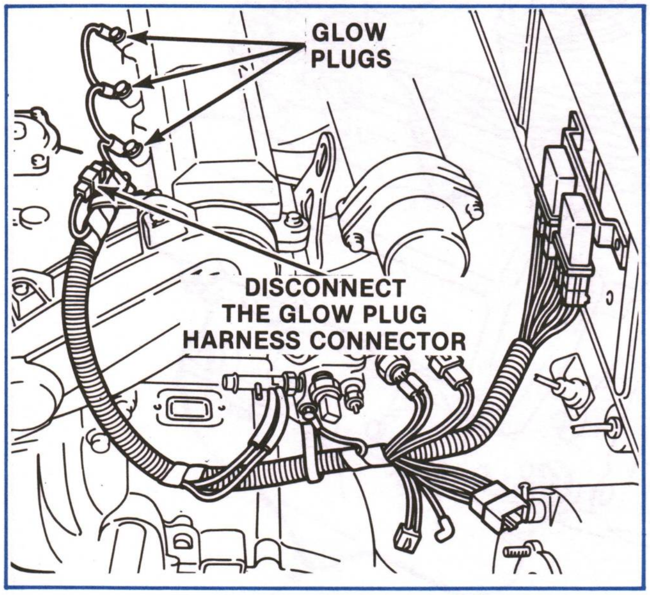


Figure 10. Disconnecting the Glow Plug Harness

CAUTION: Allowing a glow plug connector to ground when the key is turned to the ON position during the compression test could burn out the entire glow plug system. In most cases it will blow the fuse on the glow plug module or glow plug harness.

3. Disconnect the fuel cutoff solenoid to prevent the engine from starting.

NOTE: The engine probably would not start because it cannot build up compression in any of the cylinders except the one being tested. Shutting off the fuel solenoid will prevent fuel from coming out through the glow plug holes.

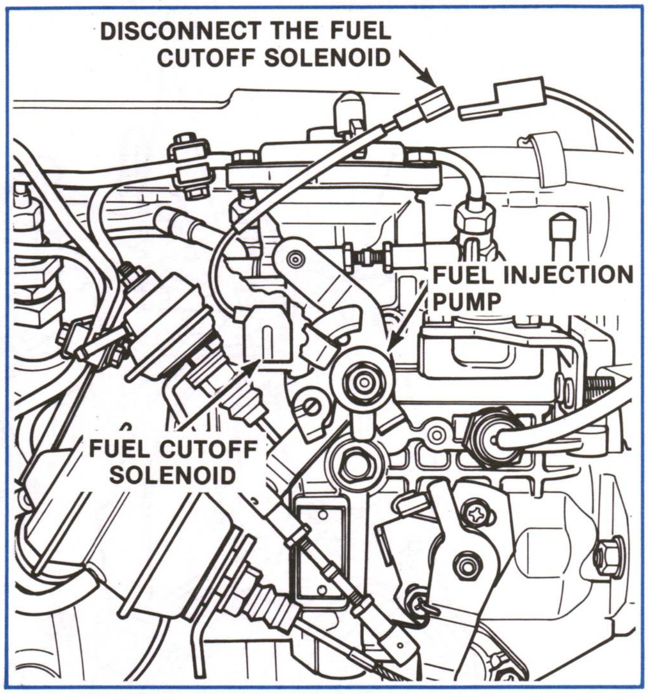


Figure 11. Disconnecting the Fuel Cutoff Solenoid

CAUTION: Fuel spurting out of the glow plug holes could possibly cause a fire.

4. Check each cylinder, allowing about six "puffs" each. This should be enough to build up compression in each cylinder.
5. Record the results from each cylinder and check them against specifications.

Should one or more of the cylinders not reach specifications, further testing will have to be done to determine if the problem area is with the rings, valves, or head gasket. Do not squirt oil into a cylinder to try to seal up the rings. The oil is combustible and could ignite. To determine where the cylinder is losing compression, perform a cylinder leak test.

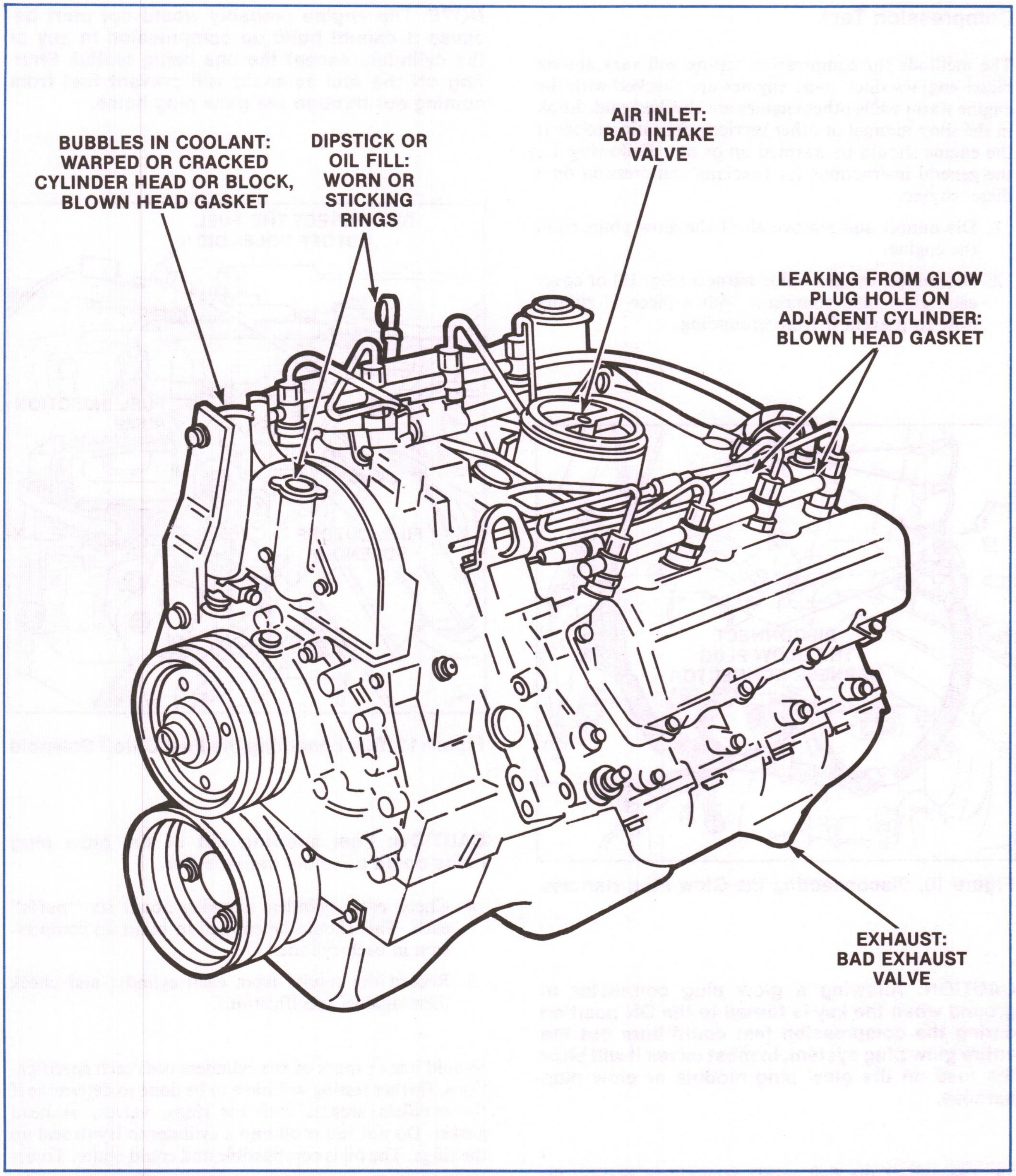

BUBBLES IN COOLANT: WARPED OR CRACKED CYLINDER HEAD OR BLOCK, BLOWN HEAD GASKET
DIPSTICK OR OIL FILL: WORN OR STICKING RINGS
AIR INLET: BAD INTAKE VALVE
LEAKING FROM GLOW PLUG HOLE ON ADJACENT CYLINDER: BLOWN HEAD GASKET
EXHAUST: BAD EXHAUST VALVE

Figure 12. Leak Points

Cylinder Leak Test

As stated earlier, it is not necessary to use a regular cylinder leak tester that is capable of measuring the percent of leakage from each cylinder. Essentially, what must be done is to warm the engine up to operating temperature. Then place each piston at top-dead-center (TDC) on the compression stroke and pressurize the cylinder with compressed air to about 70 to 200 psi. If there is a problem, it will be evident by air leaking from the engine at different points (Fig. 12).

NOTE: Watch the engine fans or pulleys. If they move, the cylinder was not at TDC and it will be necessary to place the cylinder at TDC on the compression stroke again.

- Air leaking from the air inlet indicates a bad intake valve.
- Air leaking from the exhaust indicates a bad exhaust valve.
- Air leaking from the dipstick or oil fill indicates that there are worn or sticking rings.
- Air leaking from the glow plug hole of a cylinder next to the one being tested indicates that the head gasket is blown between the two cylinders.
- Air bubbles in the radiator indicate that the cylinder block or head may be warped or cracked, or the head gasket may be blown.

One of the most important parts of diagnosing the diesel engine is determining where the problem originates so that it can be repaired without disturbing engine components that are operating normally. Use the diagnostic tests and the shop manual to help determine where a problem is located and what must be done to repair it. If a few valves are leaking, it is not necessary to overhaul the entire engine.

Oil Leak Diagnosis

Oil leaks can be difficult to locate on diesels. The best way to locate the hard-to-find oil leak is to wash the engine, or clean the area of the leak. Remember, that diesel engines can only be washed when they are cold. Never wash a warm diesel engine because it may cause the fuel injection pump or the injectors to seize.

NOTE: Clearances within the fuel injection pump and injectors can be as close as sixty millionths of an inch (0.000060 in). A sudden change in temperature (such as cool water hitting a hot injection pump or fuel injector) can cause the outer case to contract and seize the inner components.

After cleaning the area of the leak, spray aerosol powder on any mating surfaces, gaskets or seals where a leak is possible. Run the engine and examine the possible leak areas closely. The oil leak should show up quickly as a dark line on the white powder. Once the leak is found, it can then be repaired.

While looking for the leak, it is necessary to have the engine running so that the oil is flowing and the crankcase is pressurized. It is not necessary to rev the engine to hold it at high rpms with the thought that this will cause more pressure inside the crankcase.

There are special tools that are available from the Rotunda Equipment Catalog that are specifically used for oil leak detection. They are:

- 072-00003 Leak Test Kit (Pressure Type)
- 072-00007 Oil Leak Detector (Black Light Type)

If these tools are available, they can be used instead of the aerosol powder method. Follow the manufacturer's instructions when using these tools.

CLEANING AND INSPECTION

Clean and inspect parts thoroughly by following the recommended procedures. When inspection reveals abnormal wear or part failure, it is very important to identify and correct the cause or causes to prevent any reoccurrence. Consult the shop manual for particular cleaning and inspection procedures.

ENGINE CLEANING

The engine must be cleaned before starting any major service work. The cleaning must be thorough since dirt and/or abrasives that are not removed can get inside the engine and later ruin an otherwise perfect job.

While the engine can be cleaned before it is removed from the vehicle, the best method is to clean after removal when all areas are more accessible.

Before cleaning, remove electrical components and other parts which might be damaged by cleaning. Cover or plug all openings. Units that are not removed should be completely covered. Also, it is a good idea to let the engine cool to ambient temperature.

If the engine manual specifies a particular cleaning method, follow it; otherwise, use a suitable solvent, steam, or a brush with water and detergent.

ENGINE DISASSEMBLY TECHNIQUES

PREOVERHAUL CONSIDERATIONS

Before removing an engine or beginning an in-chassis overhaul, there are some procedures that must be followed.

First, clean the engine. The less dirt and grime present on the engine, the less chance of contaminating the rebuild. Remember, that lack of cleanliness during an overhaul is the biggest problem facing the technician. It is important to work carefully on this type of engine.

When cleaning the engine, follow the same procedure that was recommended earlier in the oil leak diagnosis section. Clean the engine while it is cold to prevent seizing of the fuel injection pump and injectors. Also, be sure that everything is sealed up, no loose connections, and is protected from the engine cleaner and water, if it is necessary.

After cleaning the engine, begin the overhaul by following the procedures listed in the shop manual. Whether the overhaul is light, like a cylinder head R&R, or it is a complete rebuild with the engine out of the vehicle; it will be necessary to disconnect the fuel system. The fuel system is the most sensitive area of a diesel engine to contamination. For this reason it is important to use the fuel system caps (Fig. 13) to prevent the entry of dirt into the engine.

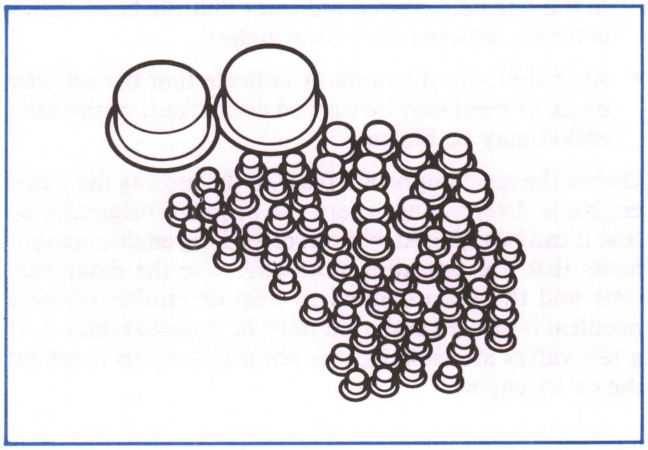


Figure 13. Fuel System Caps

Another technique that may help, especially in the case of a light overhaul where the short block is not serviced, is to set the number one piston at top-dead-center (TDC) on the compression stroke before removing the cylinder head. This will help to ensure that when the cylinder head goes back on that everything is in place.

NOTE: It may be necessary on some engines to set the #1 piston at a certain point before top-dead-center before removing the cylinder head. Check the appropriate shop manual for specific instructions.

If the pistons have to be turned to No. 1 TDC after the head is put back on the engine, there is a very good chance that the valves and pistons may hit because of the tight valve to piston clearance. In some cases, it may be impossible to get the engine set to No. 1 TDC without taking the cylinder head back off, or removing the camshaft so that none of the valves are down. Set the engine to No. 1 TDC before performing the work.

TIMING BELT REMOVAL

On engines that use a timing belt(s), remember that they are directional. If the belt is to be reused, mark the direction of engine rotation (Fig. 14) before removal. Installing the belt in the opposite direction may cause it to fail, which would cause the valves to strike the pistons if the belt broke or jumped timing.

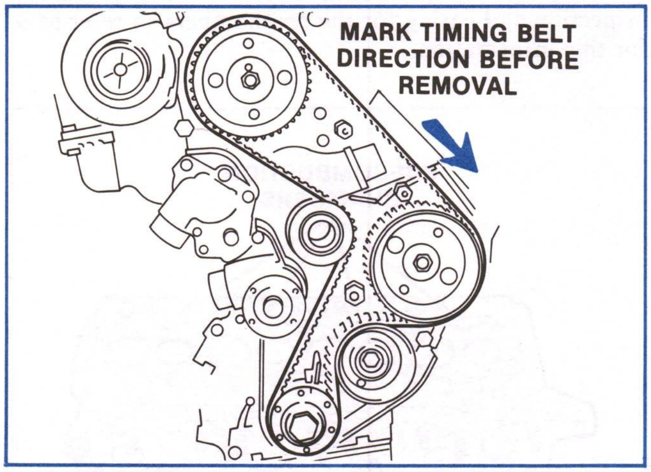


Figure 14. Marking Timing Belt Direction

After the timing belt is removed, do not turn the camshaft or crankshaft (Fig. 15) until the head is removed. If either shaft is turned, the pistons and valves could collide.

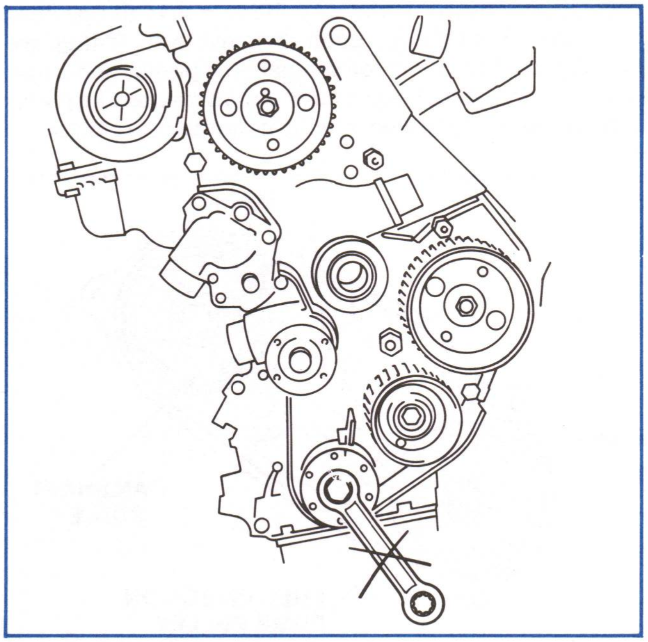


Figure 15. Do Not Rotate the Camshaft or Crankshaft Without the Timing Belt

Timing marks on the diesel (Fig. 16) are usually well scribed and easy to find. However, it is a good idea to check timing sprockets or gears to ensure that they are clearly indexed to the camshaft and crankshaft. Scribe the marks, if necessary.

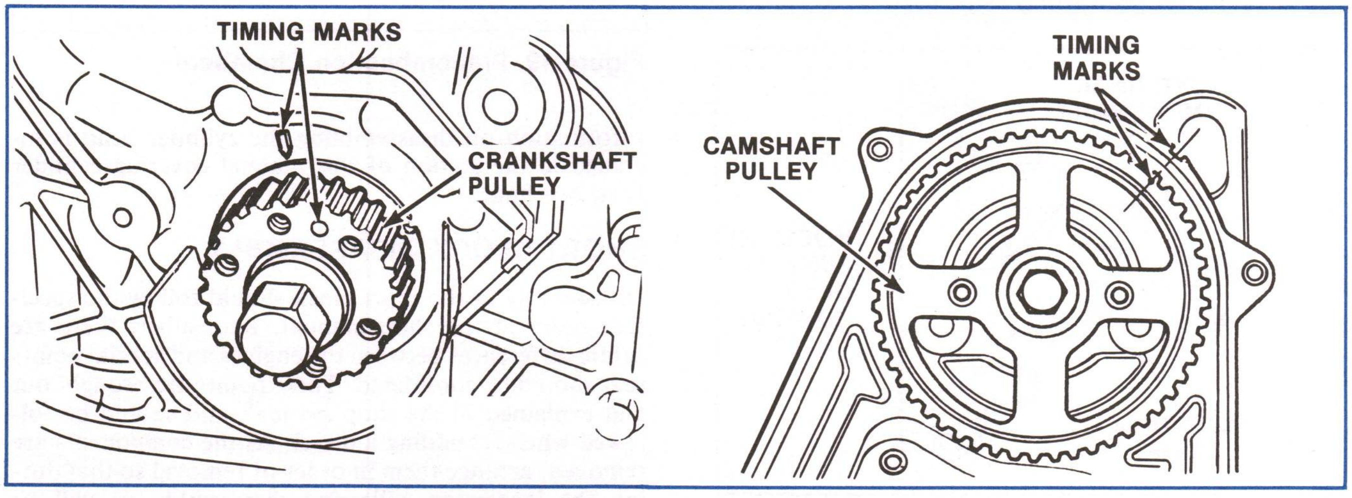


Figure 16. Examples of Timing Marks on Camshaft and Fuel Injection Pump Sprockets

ENGINE DISASSEMBLY TECHNIQUES

FUEL INJECTION PUMP REMOVAL

When removing the fuel injection pump, follow the shop manual procedures exactly. This component is a precise piece of equipment, it cannot be dropped, treated roughly, or abused in any way. Be sure that all openings are capped immediately upon their removal. If they are not, dirt or dust could contaminate the pump, and cause it to fail soon after it is put back into use. After the pump is removed, cover it and keep it in a clean safe place.

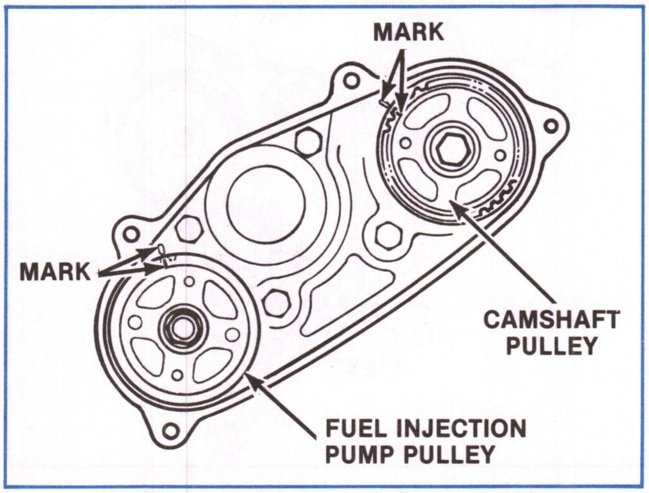


Figure 17. Fuel Injection Pump Sprocket

NOTE: The fuel injection pump is timed directly to the camshaft. Be sure that the proper procedure is followed when reinstalling the fuel injection pump; otherwise, the engine probably will not start. There should be marks on the fuel injection pump drive sprocket (Fig. 17) and sometimes on or in the fuel injection pump (Fig. 18).

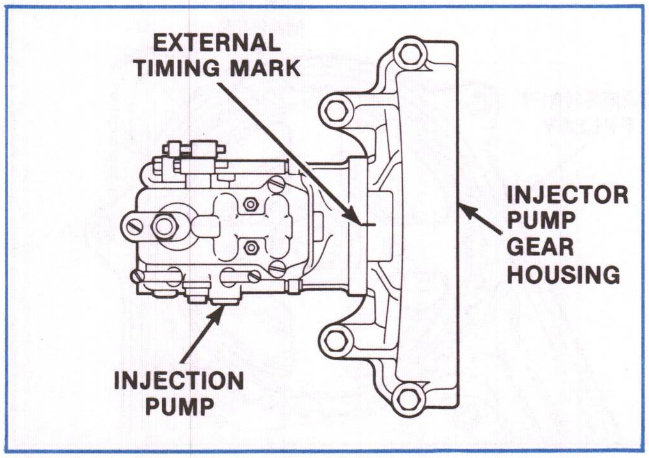


Figure 18. Fuel Injection Pump Timing Mark

CYLINDER HEAD REMOVAL

Use extreme care when removing the cylinder head bolts from diesel engines. Especially cylinder heads that are made of aluminum. Failure to remove the cylinder head bolts in the order specified in the shop manual can cause the head to warp, or in extreme cases crack. Cylinder head warp cannot be corrected on most diesel engines because it would drastically alter the compression ratio. A warped cylinder head is useless and must be replaced, so remember that the loosening procedure must be followed.

Also, notice the precombustion chambers (Fig. 19) that are in the cylinder head. On some engines they are supposed to be loose, while on other engines, a loose prechamber would be cause to discard the cylinder head. The shop manual contains the necessary instructions for inspecting and caring for the prechambers so refer to it for this information.

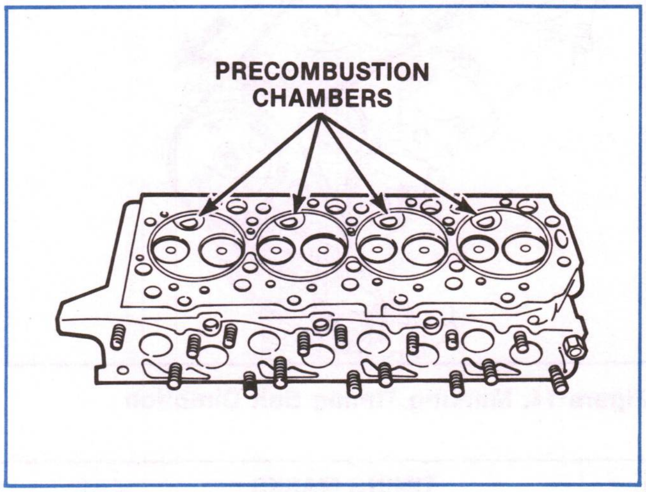


Figure 19. Precombustion Chambers

Information on disassembling the cylinder head is included in the section of this manual covering cylinder head overhaul.

SHORT BLOCK DISASSEMBLY

Disassembly of the short block should follow the specified order in the shop manual. Remember, there are subtle differences between the engines and special points that should be considered. These points are brought out and explained in the shop manual, and should be followed when rebuilding a diesel. As the components are removed, arrange them in order of removal so that during the inspection following disassembly, it will be evident where each part is located.

ENGINE DISASSEMBLY TECHNIQUES

Except for the special points on each engine, which are highlighted in the shop manual, actual engine disassembly is not that different from gasoline engines. There are some points that are fairly common to diesel engines which are not always attributed to gasoline engines and should be covered.

Piston Cooling Jets

Piston cooling jets (Fig. 20) are found on almost all diesel engines. They may be known by other names, such as oil spray tubes or jets. They are extremely important to the life of the engine, and damage to them can almost certainly cause engine failure soon after the engine is run. In most cases, the piston cooling jets have to be removed before attempting piston or ring service or before pulling the crankshaft.

Their purpose is to provide a spray of oil into the bottom of the piston (Fig. 21) to absorb some of the heat that builds up from combustion. Remember, that on diesels the pistons are exposed to much more heat and pressure than they would be in a gasoline engine. They need the cooling effect of the oil spray to operate properly.

There are different methods for removing the cooling jets because sometimes they are pressed in, and at other times they are held in place by a bolt. Use the shop manual to determine how the cooling jet should be removed so that it is not damaged. Also, remember that during engine assembly when the piston cooling jets are installed, some engines require that the jets be aligned through a special procedure. Failure to go through the alignment procedure on the engines that require it could result in engine failure.

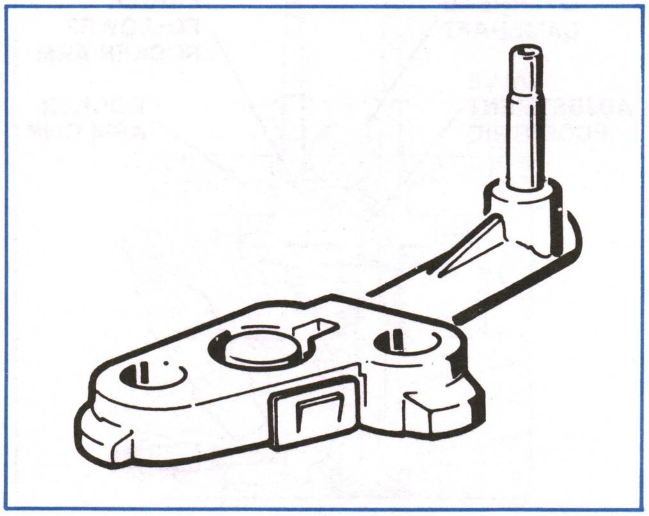


Figure 20. Piston Cooling Jet

Bearing Cap Removal

It is very important that the rod bearing caps and main bearing caps are numbered and have a mark noting the direction that they should be installed. If for some reason there are none, mark them with an etching tool. Do not stamp them. Stamping them can cause damage and possible misalignment. To keep the rods and rod bearing caps separated, reinstall the rod cap on the rod as soon as it is removed.

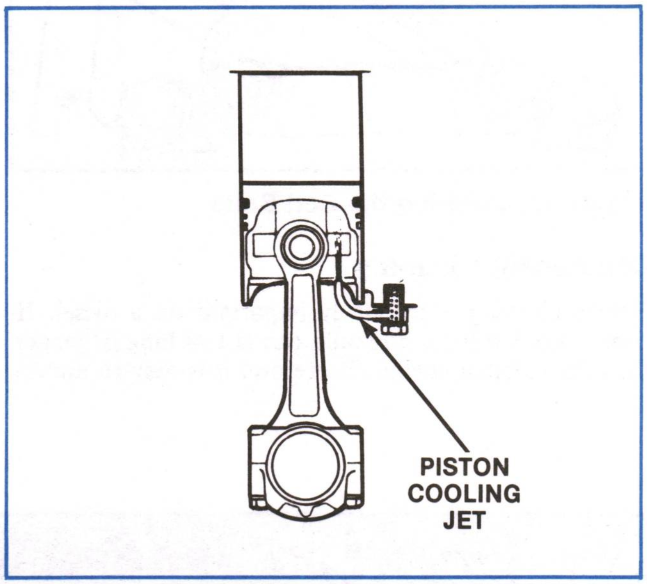


Figure 21. Piston Cooling Jet in Operation

Piston Removal

Before removing the pistons, check to see if there are ridges at the tops of the cylinders. If so, ream the ridges according to the shop manual procedures before removing the pistons.

It is also a good idea to cover the connecting rod bolts with pieces of rubber hose (Fig. 22) to protect the crankshaft journals from damage. In the special tool kit on some engines, there are piston alignment pins which are normally used during engine assembly to protect the piston cooling jets. These tools can be used during disassembly to protect the crankshaft journals from being marred by the rod bolts.

After removing the pistons and main bearing caps, the crankshaft can be carefully lifted from the block. After removing anything else that needs to be taken off, the block can be cleaned and degreased along with the other components.

ENGINE DISASSEMBLY TECHNIQUES

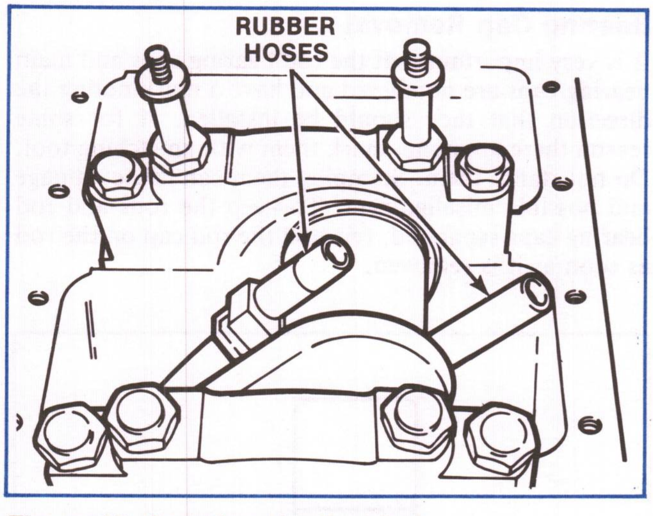


Figure 22. Covering the Rod Bolts

Component Cleaning

Engine cleaning is extremely important on a diesel. If completed correctly, a rebuild can last as long or longer than the original engine. Therefore, it is easy to understand why one would want a thorough job of cleaning done on the engine. It is important that the oil galleys be scrubbed; the freeze plugs are removed; the water jacket is thoroughly flushed; and new freeze plugs are installed. With everything clean it is much easier to perform an inspection.

If degreasing equipment isn't available in the shop, scrub the components down with detergent and water, and then rinse thoroughly. Remember, cleanliness is very important on a diesel rebuild. Clean the inner components such as the camshaft, lifters, pushrods, rocker arms, crankshaft, etc. with a suitable solvent. Bead blast pistons (if they are to be reused), rods, and valves to clean them up for close inspection.

CYLINDER HEAD INSPECTION AND SERVICE

First, disassemble the cylinder head before performing any inspection or service. Normally, this is the same procedure completed on a gasoline engine. Remove the components, valves, valve springs, camshaft, etc., from the cylinder head. Inspect them carefully. Notice that the design of some valve trains used on diesel engines is quite different from the valve trains commonly used on gasoline engines.

Use the shop manual when disassembling the cylinder head. This is especially true on the overhead camshaft engines, which can be fairly complicated. Notice the cylinder head cross section in Figure 23. It is different compared to the cylinder heads on the gasoline engines in the Ford vehicles. This particular diesel cylinder head makes use of:

- Finger follower rocker arms
- Clips holding the rocker arm in place
- Eccentrically adjusted valves

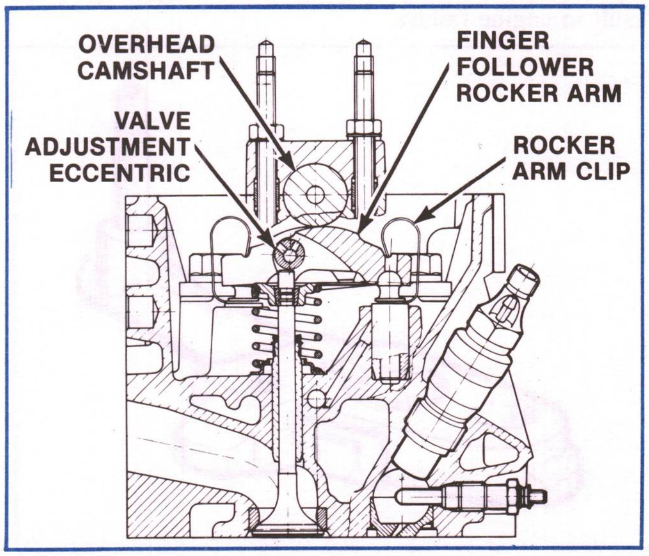


Figure 23. Cylinder Head Cross Section

CYLINDER HEAD INSPECTION AND SERVICE

NOTE: Probably the most important procedure in cylinder head disassembly on the overhead camshaft models is camshaft removal. If the cam is not removed correctly, it can be snapped in half. This can happen very easily if the cam is not positioned correctly and if the cam bearing caps are not removed in the order specified.

This is just an example of what can be found in the Ford diesels, other cylinder heads are just as different and do not look anything like this one. Be sure to use the shop manual, at least on the first time through to help things go smoothly and to identify the special tools and procedures that are needed on the different cylinder heads.

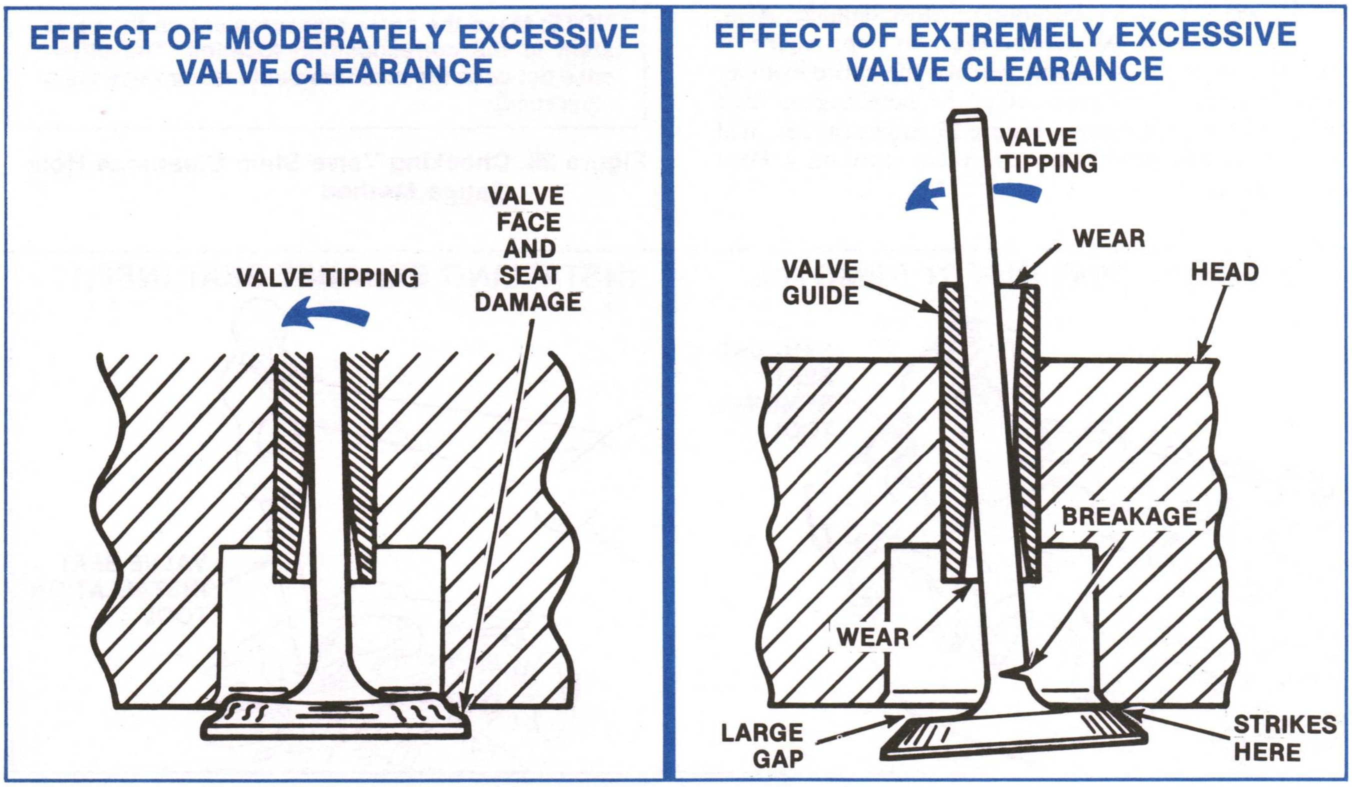
CYLINDER HEAD AND VALVE INSPECTION

After the cylinder head is disassembled and cleaned, inspect it. First, check the cylinder head for warpage using a straightedge and feeler gauge. If the cylinder head is warped beyond specifications, it must be replaced. DO NOT RESURFACE A DIESEL CYLINDER HEAD. Next, check for cracking in the cylinder head especially in the area of the valve seats and the combustion chamber. If there is cracking in these locations, replace the head. In most cases, the valve seats are not replaceable, check the shop manual for reference.

NOTE: A warped cylinder head is often the result of an overheated engine. A cracked cylinder head is often the result of air pockets in the water jacket.

After checking the cylinder head for warping or cracking, inspect for worn valve guides. Excessive guide clearance (Fig. 24) prevents adequate cooling of the valve through the guide and allows the valve to tilt or tip. This can cause valve breakage at high engine speed. These conditions prevent good seating and promote leakage past the valve face.

Since diesels rely on extremely high pressures in the combustion chamber to heat the air that ignites the fuel, anything that allows the pressure to escape will affect ignition of the fuel. If the leakage past the face of the valve is enough, the fuel will not ignite. This is different from a gasoline engine because the air/fuel mixture will normally ignite even with leaky valves because it has a spark to set it off.


EFFECT OF MODERATELY EXCESSIVE VALVE CLEARANCE

EFFECT OF EXTREMELY EXCESSIVE VALVE CLEARANCE

Figure 24. Effect of Excessive Valve Clearance

CYLINDER HEAD INSPECTION AND SERVICE

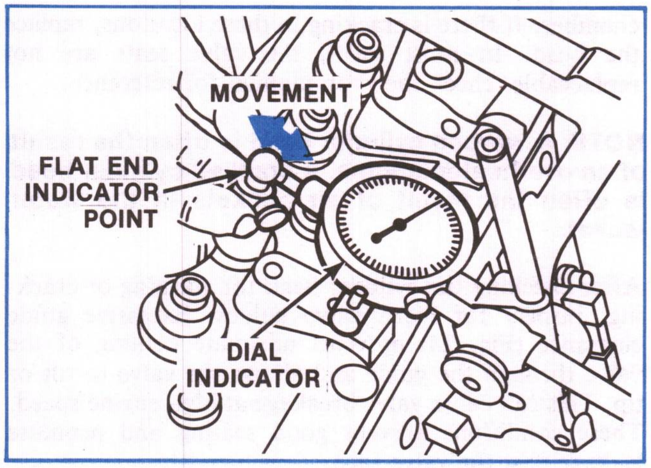
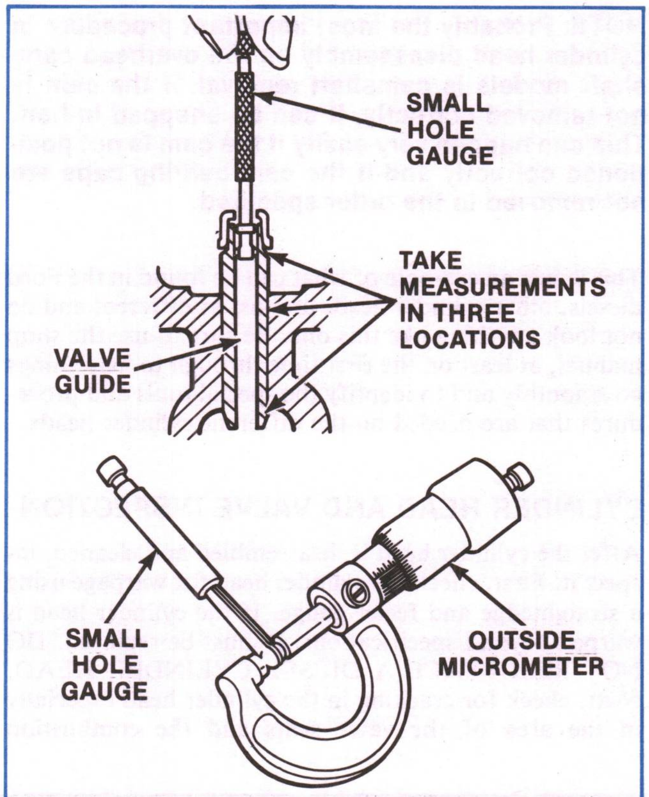


Figure 25. Checking Valve Stem Clearance Wobble Method

To check the valve guide wear, use the wobble method (Fig. 25) or the hole gauge method (Fig. 26). If the clearance is excessive, follow the instructions in the shop manual for replacing or knurling the guides.

Valve Seat Inspection and Service

Prior to valve seat reconditioning, clean the valve seats and inspect for cracks, burning, or other damage. Also, check for tightness. As stated earlier, on some engines if the valve seats are damaged, replace the entire cylinder head. This is not the case on all of the diesel engines used by Ford Motor Company. Figure 27 shows the removal and installation process for the valve seats on a Ford diesel engine.



NOTE: Make the same measurement on the valve stem in the corresponding location. The difference between the measurements is the valve stem clearance.

Figure 26. Checking Valve Stem Clearance Hole Gauge Method

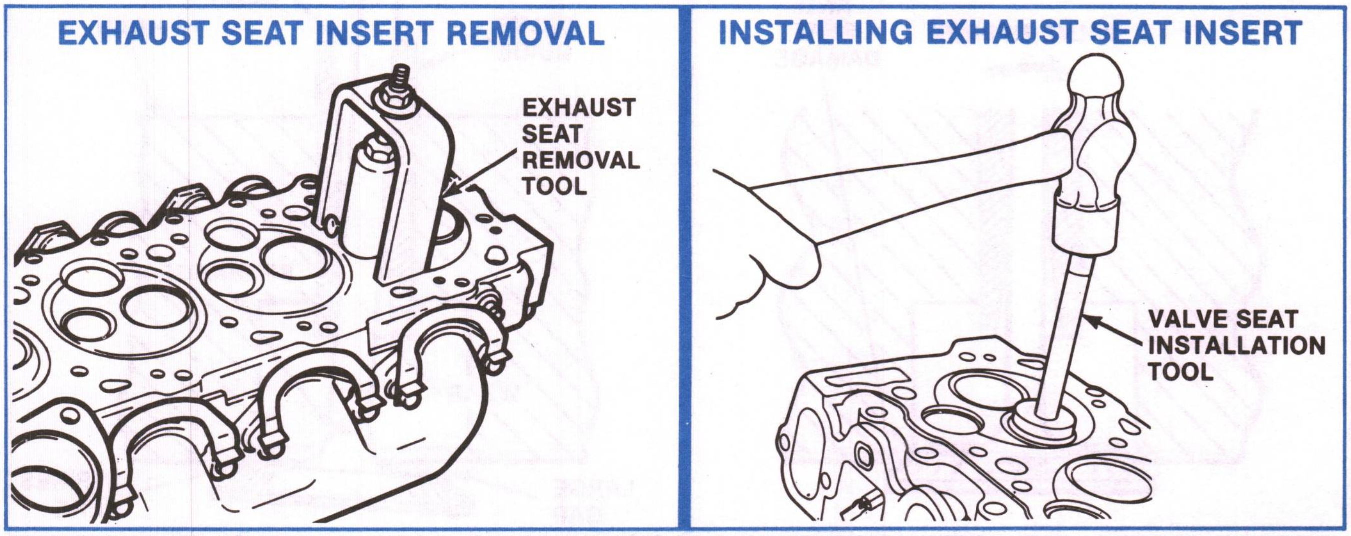

EXHAUST SEAT INSERT REMOVAL
EXHAUST SEAT REMOVAL TOOL
INSTALLING EXHAUST SEAT INSERT
VALVE SEAT INSTALLATION TOOL

Figure 27. R & R Valve Seats

CYLINDER HEAD INSPECTION AND SERVICE

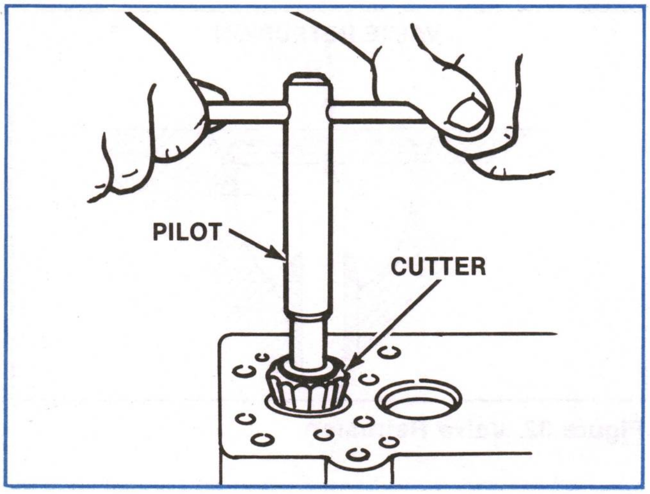


Figure 28. Valve Seat Cutter

Complete the refacing of the valve seats carefully so that the finished seat and the valve face have the specified interference fit. This fit must seal in the extremely high pressures produced by the diesel compression stroke. Without the high pressure inside the combustion chamber, heat will not be sufficient to ignite the fuel, and engine performance will be poor.

NOTE: The importance of a quality valve job on a diesel cannot be stressed enough. Without proper sealing of the valves, the engine just does not run correctly.

In some cases, grinding or machining the valve seats is not allowed; therefore, cut the seats using a valve seat cutter similar to the one shown in Figure 28.

No matter what method is specified for facing the valve seats, follow the specific instructions and specifications (Fig. 29) that are shown in the shop manual.

Check the diesel valve seats for runout (Fig. 30) using a valve seat runout gauge (D81P-6002-E or equivalent). Measure the width of each valve seat (Fig. 31) carefully by using a scale with increments that are at least to 1/32 of an inch and/or 1 mm. If the valve seats are not within the proper limits, problems can develop:

- Too Wide—carbon build up and improper valve seating
- Too Narrow—poor valve cooling and burned valve face

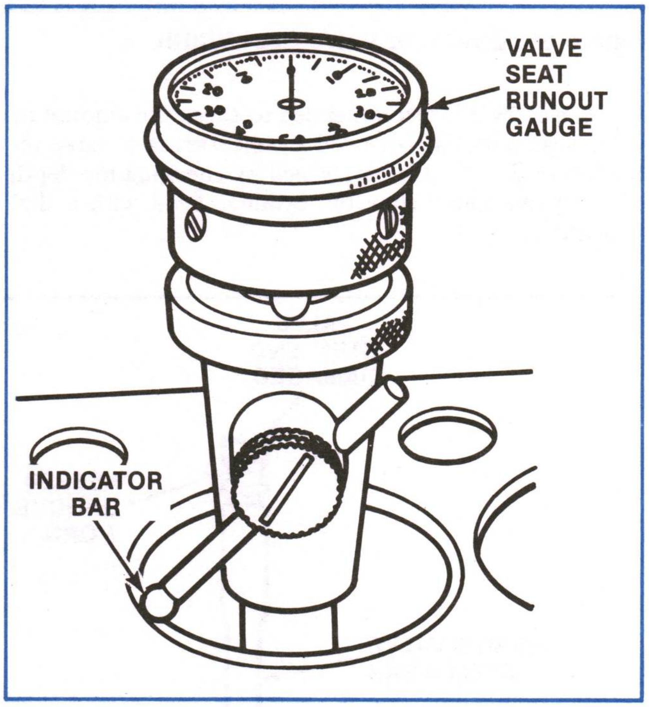


Figure 30. Checking Valve Seat Runout

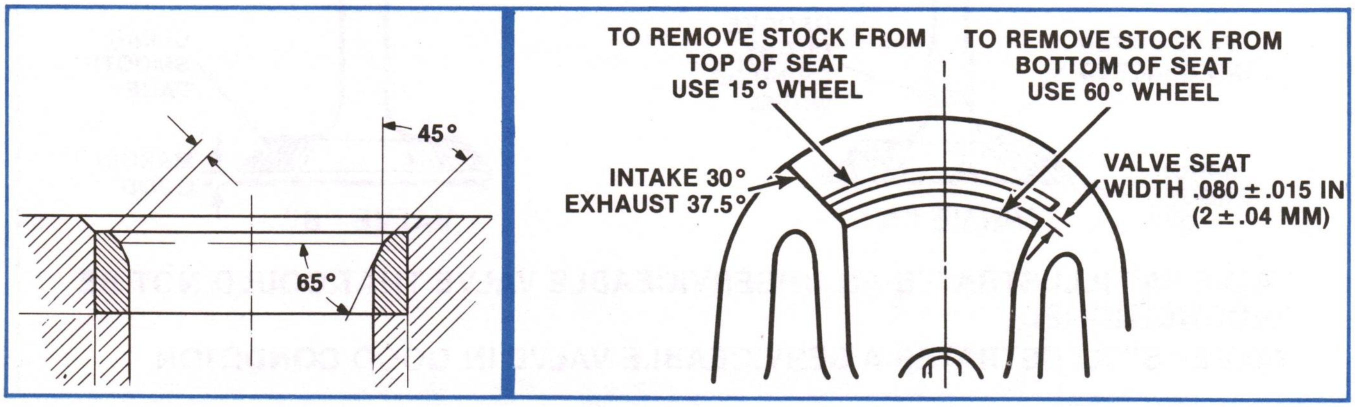


Figure 29. Examples of Valve Seat Specifications Used in Different Ford Diesel Engines

CYLINDER HEAD INSPECTION AND SERVICE

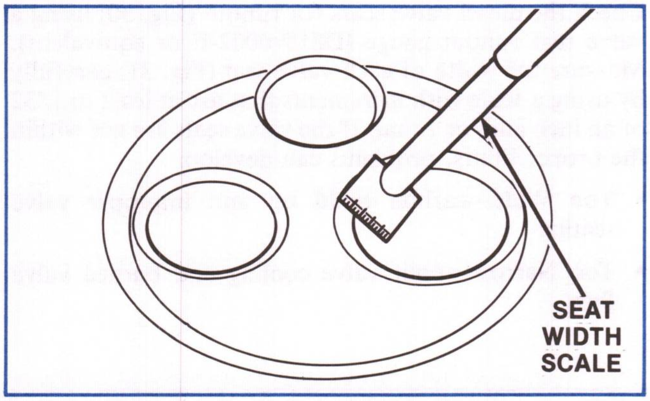


Figure 31. Checking Valve Seat Width

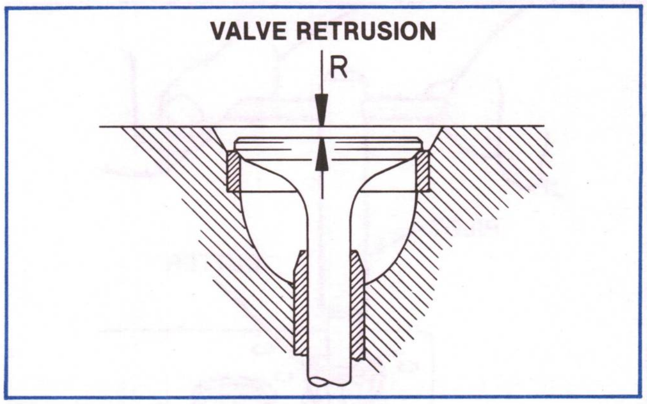


Figure 32. Valve Retrusion

In some cases it is recommended to check the amount of valve seat material removed by measuring a valve retrusion (Fig. 32). It is performed by checking the depth of the valve face below the cylinder head with a dial indicator.

Valve Inspection and Service

Examine the condition of an intake or exhaust valve carefully before allowing a valve to be reused (Fig. 33). Check each valve for several dimensions (Fig. 34).

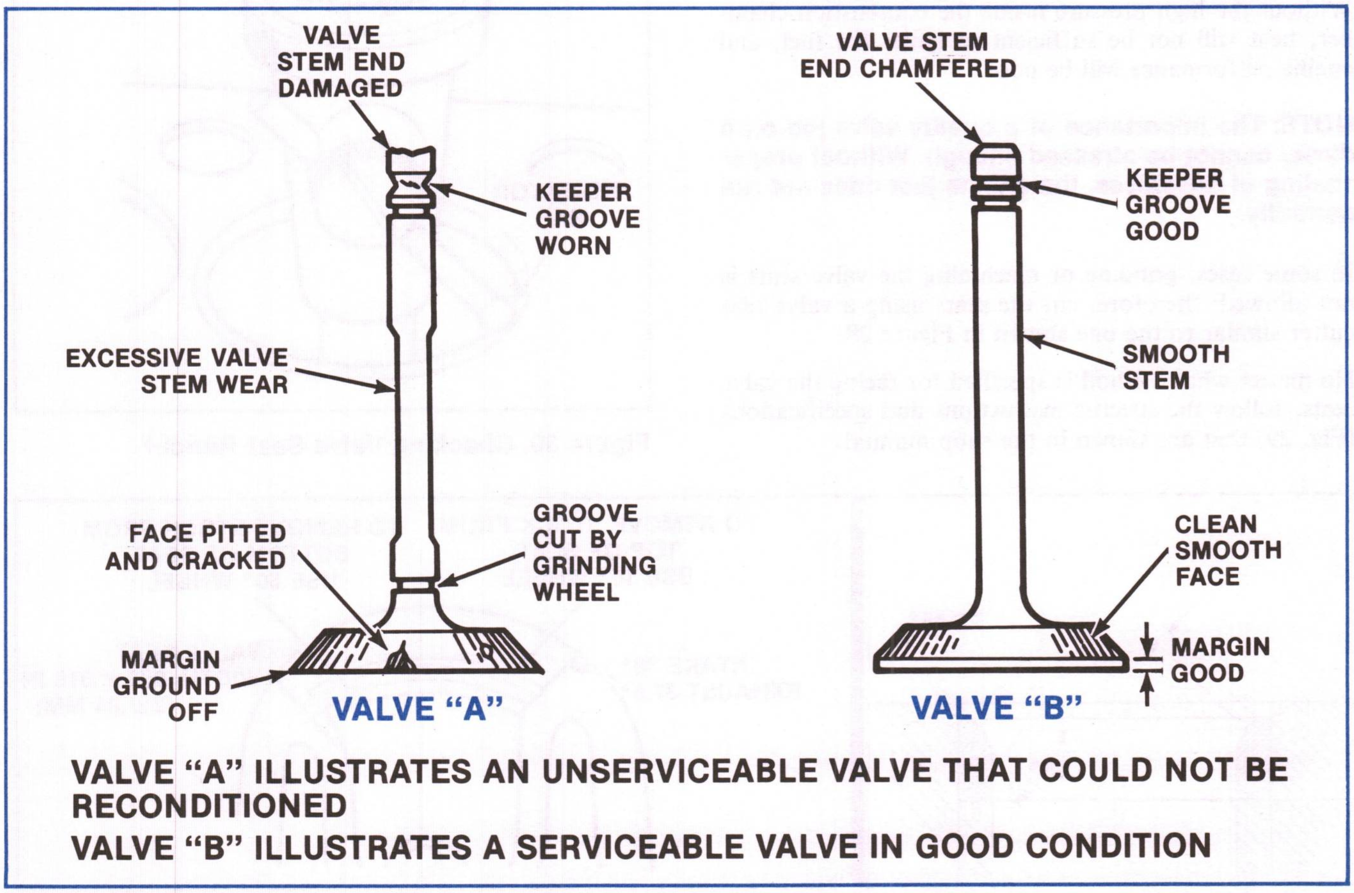


Figure 33. Examine the Condition of the Valve

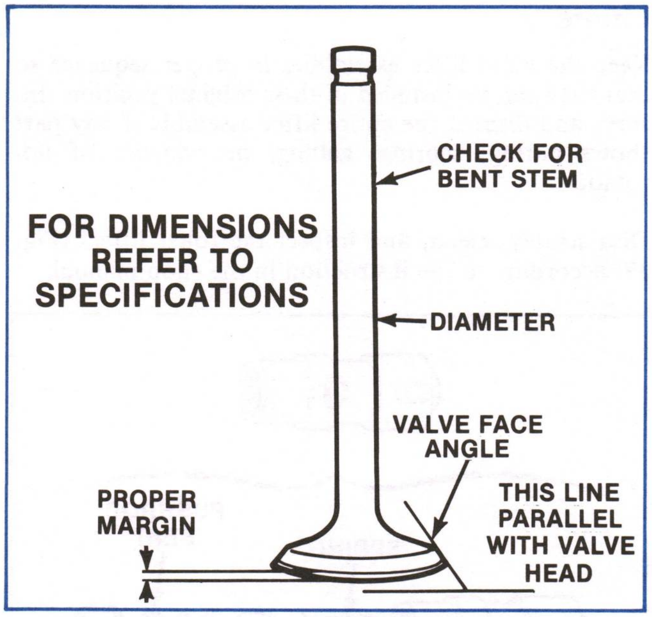

CHECK FOR BENT STEM
FOR DIMENSIONS REFER TO SPECIFICATIONS
DIAMETER
VALVE FACE ANGLE
THIS LINE PARALLEL WITH VALVE HEAD
PROPER MARGIN

Figure 34. Valve Checkpoints

Reconditioning of the valves may or may not be allowed depending upon the engine because some valves are coated. If the coating were removed, the valve would quickly wear out.

NOTE: When a diesel is rebuilt because of high mileage, look for problems like peened valve faces (Fig. 35) and worn valve stems.

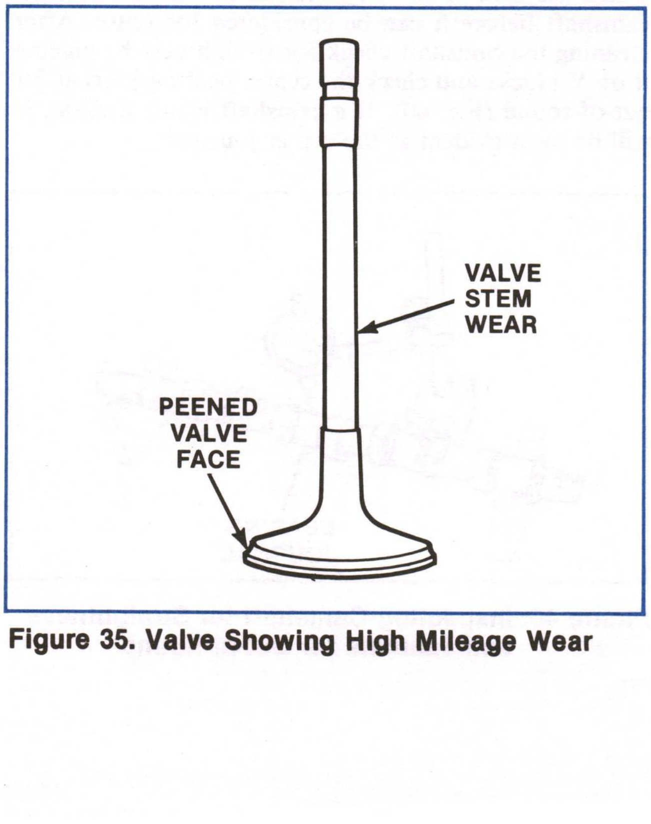


Figure 35. Valve Showing High Mileage Wear

Since the condition of the valves and valve seats is so important to holding in compression, any problem that makes the reuse of a valve questionable is reason to replace it.

Checking Valve Face and Valve Seat Contact

Check the contact point of each valve on the valve seat. The contact point should be at the approximate center of the valve face. To check the contact point, coat the valve seat with Prussian blue and set the valve in place. Press the valve against the seat while applying light pressure. Do not rotate the valve. If the blue is transferred to the center of the valve face, the contact is satisfactory. If the blue is transferred to the top edge of the valve face, lower the valve seat. If the blue is transferred to the bottom edge of the valve face, raise the valve seat.

NOTE: Never lap out the fit of the valve and seat with lapping compound.

COMPONENT INSPECTION AND SERVICE

The inspection and service of the valve spring, rocker arm, pushrod, and lifter are essentially the same on a diesel as they are on a gasoline engine. It is extremely important that all of the recommended checks for these components be completed.

Valve Springs

Inspect the valve springs for any sign of rust, corrosive etching, nicks, deep scratches, or cracks. Replace all springs with these conditions. Also, check the springs for correct pressure (Fig.36), squareness (Fig. 37), and free length.

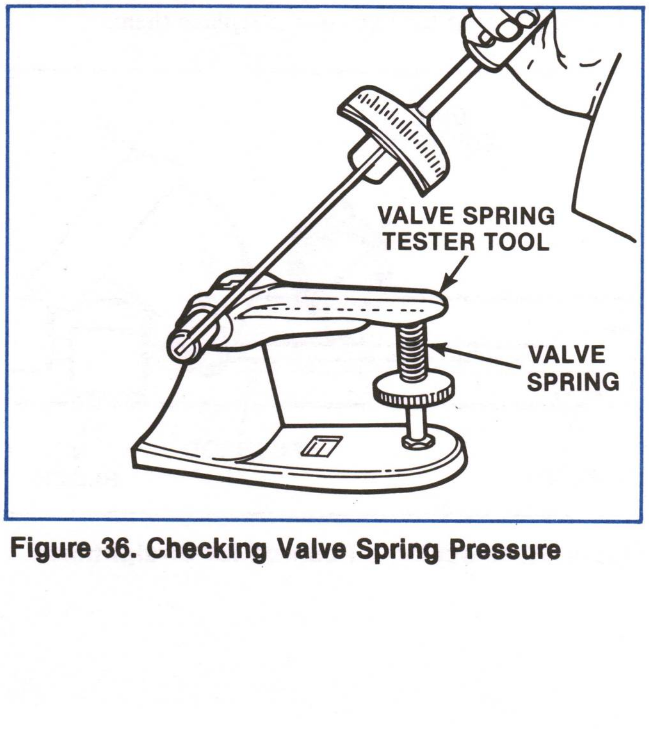


Figure 36. Checking Valve Spring Pressure

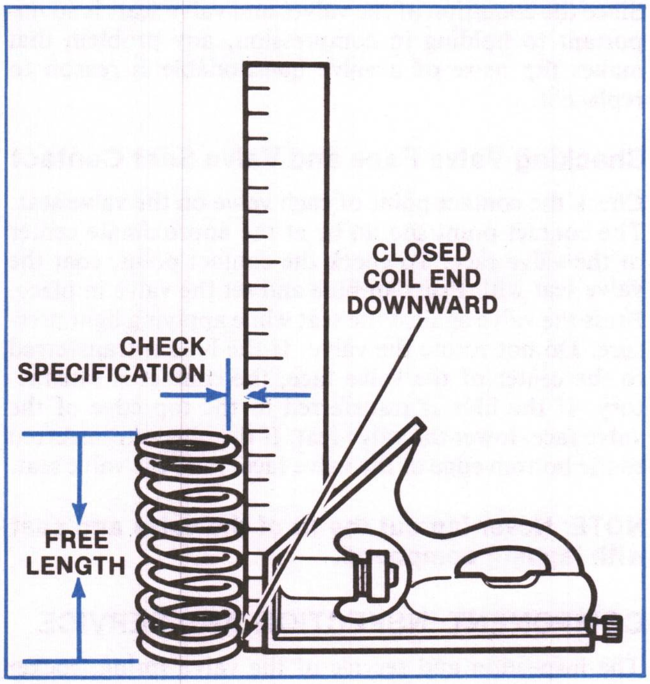


Figure 37. Checking Valve Spring for Squareness and Free Length

Rocker Arms

Inspect rocker arms for wear or damage, especially in the areas where the rocker arms contact other parts.

Pushrods

Inspect pushrods for straightness (Fig. 38) and check the ends for wear. Usually, if the end of a pushrod is worn, it will be pointed instead of round. If the pushrods are not straight, or if they are worn, replace them.

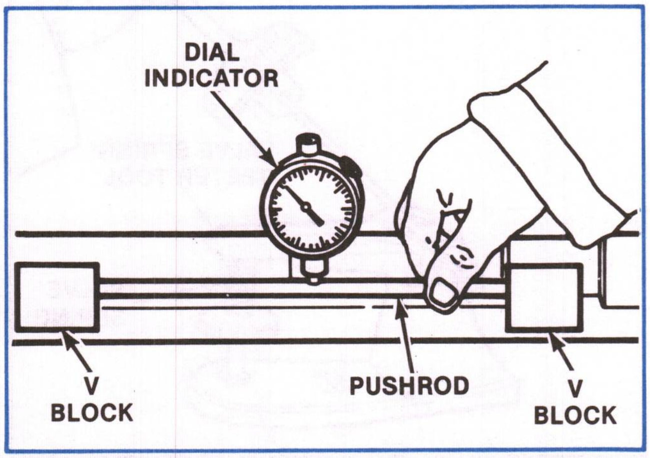


Figure 38. Checking a Pushrod for Straightness

Lifters

Keep the valve lifter assemblies in proper sequence so that they can be installed in their original position. Inspect and discard the entire lifter assembly if any part shows pitting, scoring, galling, or evidence of no-rotation.

Disassembly, clean, and inspect the roller lifters (Fig. 39) according to the instruction in the shop manual.

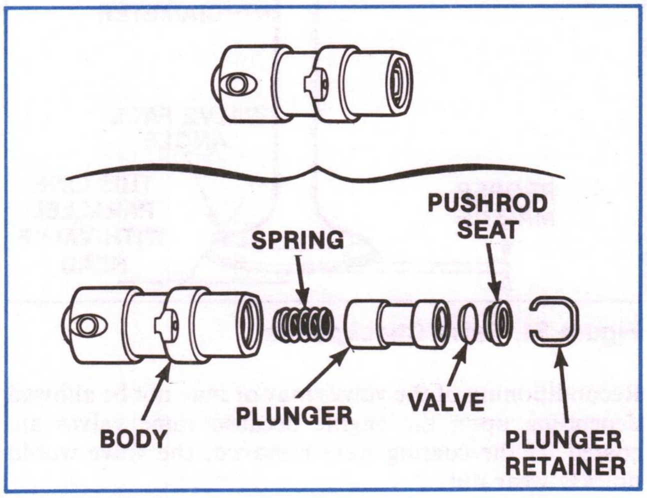


Figure 39. Roller Lifter

CAMSHAFT INSPECTION AND SERVICE

There are several checks which must be made on the camshaft before it can be considered for reuse. After cleaning the camshaft check for straightness by placing it on V-blocks and check the center bearing journal for out-of-round (Fig. 40). If a camshaft is not straight, it will be most evident at the center journal.

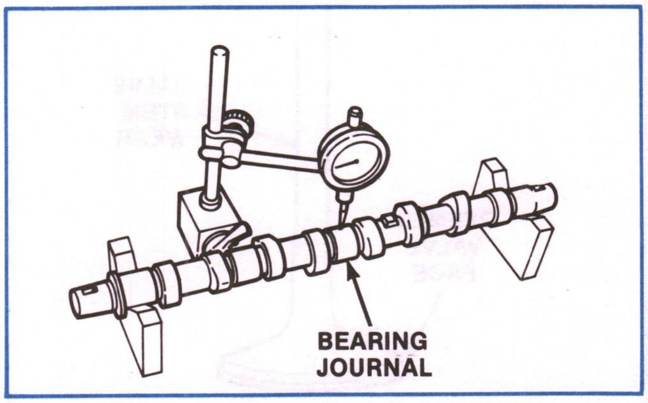


Figure 40. Inspecting Camshaft for Straightness and Journals for Out-of-Round

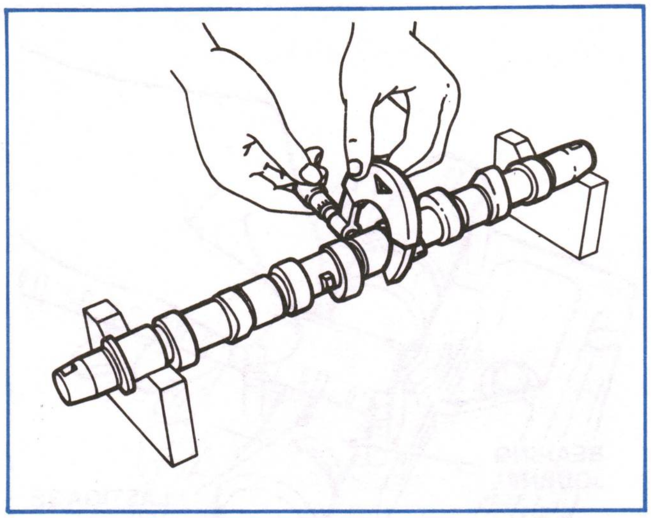


Figure 41. Checking Journal Wear

If the camshaft is straight, measure the rest of the bearing journals with the dial indicator for out of round. After completing this check, inspect the camshaft for wear at the journals and lobes. Check camshaft journal wear at each journal (Fig. 41) using a micrometer. Check each lobe by using a micrometer (Fig. 42).

NOTE: The camshaft lobe lift can also be checked at the pushrod (Fig. 43) on some engines when they are assembled.

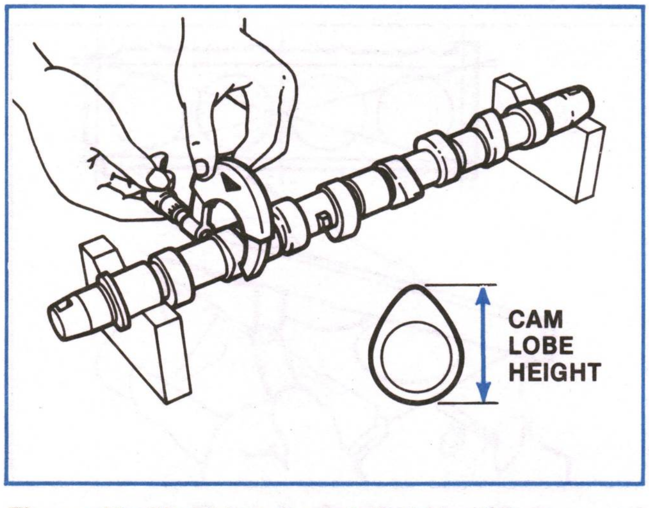


Figure 42. Checking Camshaft Lobe Wear

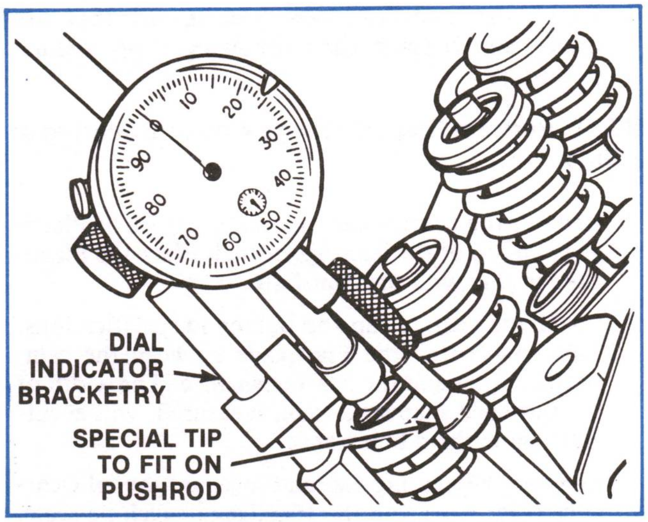


Figure 43. Checking Camshaft Lift at the Pushrod

Check camshaft wear patterns on each individual lobe. Normal wear patterns (Fig. 44) usually vary in width, and are narrower on the base circle of the cam, becoming wider toward the nose of the cam. The pattern may be a little off center and must not show across the full width of the lobe. If the lifter wear pattern extends to the edge of the cam, both the lifter and camshaft lobes will wear rapidly. Roller lifters should wear evenly on the lobe.

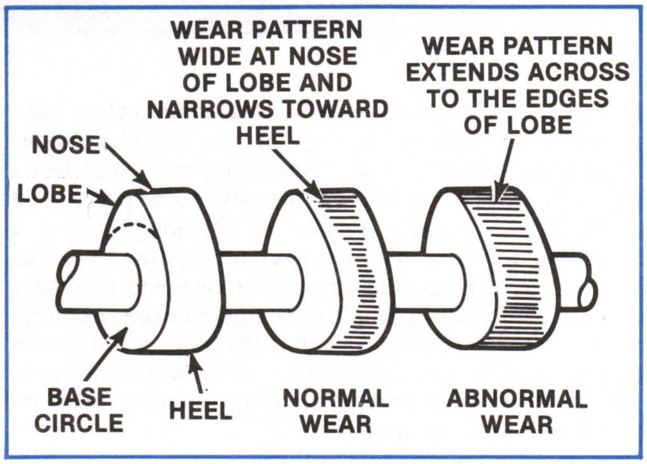

WEAR PATTERN WIDE AT NOSE OF LOBE AND NARROWS TOWARD HEEL
WEAR PATTERN EXTENDS ACROSS TO THE EDGES OF LOBE
NOSE
LOBE
BASE CIRCLE
HEEL
NORMAL WEAR
ABNORMAL WEAR

Figure 44. Camshaft Wear Patterns

Camshaft Bearings

Replace the camshaft bearings (if they are used) whenever the engine is rebuilt according to the instructions in the shop manual. On diesel engines with overhead camshafts, check the camshaft bearing oil clearance using Plastigage. To do this follow these instructions.

CYLINDER HEAD INSPECTION AND SERVICE

1. Install the camshaft, new bearings (if they are used), and bearing caps following shop manual procedure.

NOTE: Perform Steps 2, 3, and 4 on one bearing at a time.

2. Remove the bearing cap and place a piece of Plastigage on top of the bearing journal. Place the Plastigage in line with the camshaft.
3. Install the bearing cap and tighten to specifications. This will flatten the Plastigage between the camshaft journal and the bearing surface. The width of the flattened material, when measured, will accurately show the oil clearance.
4. Remove the bearing cap and measure the oil clearance (Fig. 45) using the Plastigage envelope scale. Check measurement against specifications.
5. If clearance is within specification, repeat the procedure on the next bearing. If oil clearance for any bearing exceeds specification, replace the bearings, or in some cases the cylinder head and/or bearing caps.

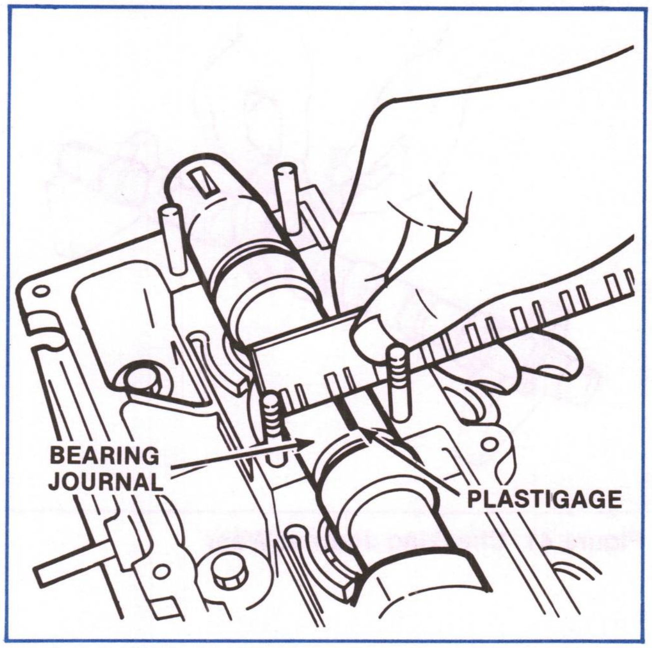


Figure 45. Checking Oil Clearance

SHORT BLOCK INSPECTION AND SERVICE

This section of the Reference Manual takes a close look at the inspection and service of the cylinder block, crankshaft, pistons, rings, connecting rods, and bearings. There are many checks that have to be performed on these components because of the longevity of a diesel. Obviously, if a diesel overhaul is going to last as long as the original, the amount of care and precision that went into putting the engine together the first time must be repeated. Keep in mind that this is not just a gasoline engine, and as a competent diesel technician it is a matter of pride in workmanship to make the overhaul better than the original.

CYLINDER BLOCK INSPECTION AND SERVICE

After the cylinder block is cleaned and degreased, inspect it carefully for cracks, especially in the cylinder walls, deck, water jackets and main bearing webs. Inspect machined gasket surfaces for burrs, nicks and scratches. Check the deck for flatness (Fig. 46) using a straightedge.

NOTE: The shop manual lists procedures and job aids to help in locating cracks in the cylinder block.

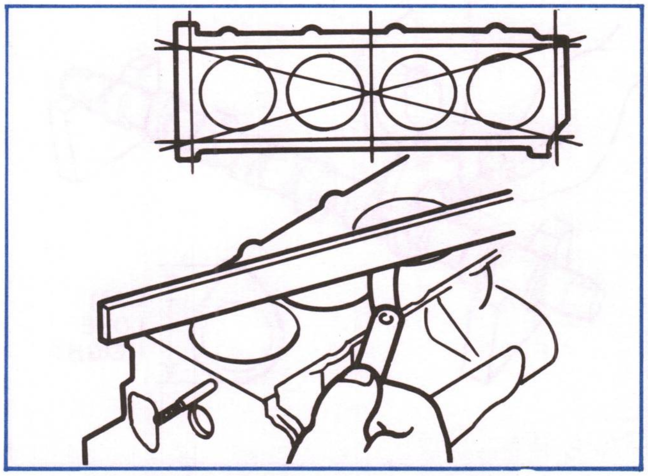


Figure 46. Checking the Deck for Flatness

NOTE: If a block is warped beyond specifications, it usually must be replaced. This is because decking a block drastically changes the already high compression ratio.

Check the main bearing bores for alignment (Fig. 47) and for out-of-round (Fig. 48). In addition to these checks, it is a good idea to run a tap into all of the threaded holes to clean up the threads, and remove any crud that may have built up in the hole.

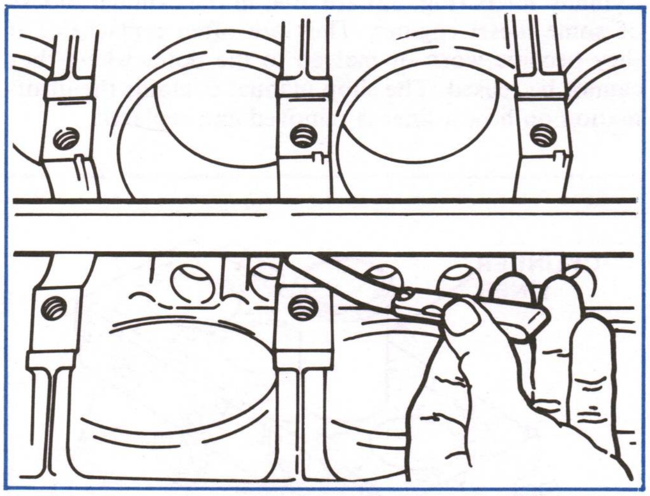


Figure 47. Checking Main Bearing Saddle Alignment with a Straightedge

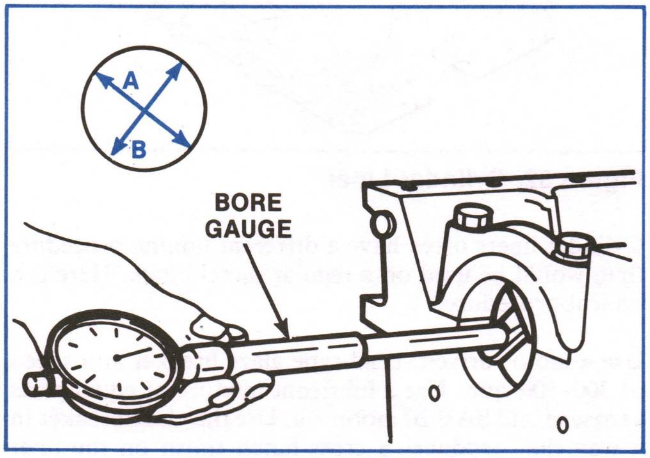


Figure 48. Checking Main Bearing Bores for Out-of-Round

NOTE: Dirty or battered threads may give false torque readings that will prevent normal tightening of bolts on reassembly. This can cause engine failure from loose engine parts.

Measure each cylinder for diameter, out-of-round; and taper (Fig. 49). If any of the cylinders are not within specification, the block can normally be repaired by boring it for oversize pistons. Be sure to check each cylinder at the six spots shown in Figure 49.

Cylinder bores normally wear in a specific way (Fig. 50) unless there is a malfunction or component failure.

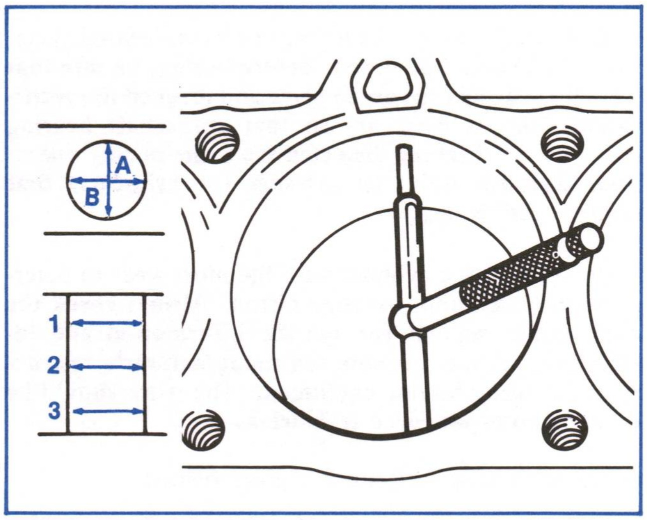


Figure 49. Checking the Cylinder Bore with a Telescoping Gauge

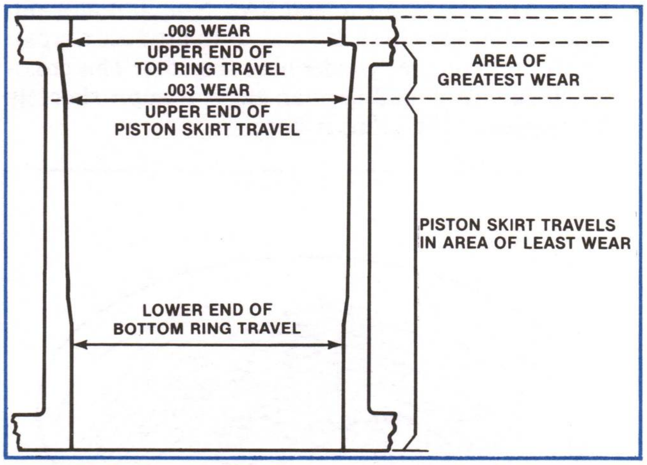

.009 WEAR
UPPER END OF TOP RING TRAVEL
.003 WEAR
UPPER END OF PISTON SKIRT TRAVEL
AREA OF GREATEST WEAR
PISTON SKIRT TRAVELS IN AREA OF LEAST WEAR
LOWER END OF BOTTOM RING TRAVEL

Figure 50. Typical Cylinder Bore Wear

Cylinder Wall Refinishing

Hone cylinder walls only when there is no visible sign of cross hatching (hone pattern) remaining; when the walls have minor scuffs or scratches; or when fitting the pistons to a specified clearance.

Determine the grade of the hone to be used by the amount of metal to be removed. Follow the instructions of the hone manufacturer. When using coarse stones to start the honing, leave enough material so that all deep hone marks can be removed with the finishing hone used to obtain proper piston clearance.

After honing, thoroughly clean the cylinder bore walls with a detergent and water solution.

Cylinder walls which are marred or worn beyond specified limits should be bored. **Before boring, be sure that all main bearing caps are in place and torqued to specification. This is necessary so that crankshaft bearing bores do not become distorted from the boring operation. Refinish only the cylinder (or cylinders) that requires refinishing.**

First, refinish the cylinder with the most wear to determine the maximum oversize piston. **Always check the appropriate manual for specific information and instructions. Always follow the manufacturer's instructions for using honing equipment. The work should be done by an experienced technician.**

A typical honing procedure is given below:

- Use a motor-driven, spring-pressure type hone at a speed of 300–500 rpm. Hones of grit sizes (180–220) will normally provide the desired bore surface finish. When honing the cylinder bores, use a lubricant of equal parts of kerosene and SAE No. 20 motor oil. Operate the hone in such a way as to produce a cross-hatch finish on the cylinder bore (Fig. 51). This cross-hatch pattern should be at an angle of approximately 30 degrees to the cylinder bore.

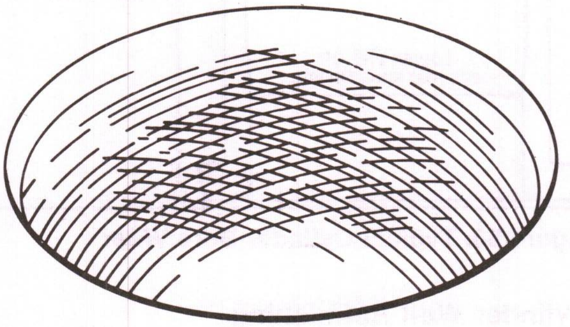


Figure 51. Cross-Hatch Pattern

After the final operation, and before you check piston fit, thoroughly clean cylinder walls with a detergent and water solution. Dry thoroughly and oil the cylinder walls. **Never use gasoline, kerosene, or commercial cleaners to clean cylinder walls. Such solvents do not remove abrasive from cylinder walls. Rapid engine wear and ring failure can result from failure to properly clean abrasives from cylinder walls.**

Cylinder Liners

Cylinder liners (Fig. 52) are used in the cylinder blocks of some diesel engines. They are often replaceable if they become worn or marred to the point where they cannot be reused. The shop manual contains the information on how a liner is removed and replaced.

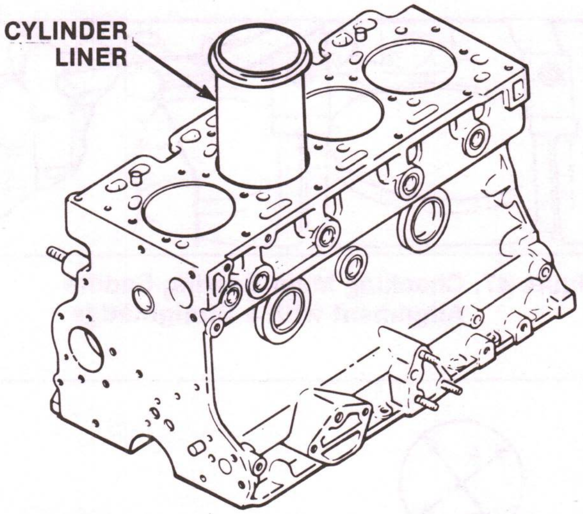


Figure 52. Cylinder Liner

Cylinder liners often have a different honing procedure than would be used on a regular diesel block. Here is a typical procedure.

Use a motor-driven, bead-type glaze breaker at a speed of 300–500 rpm. Use a lubricant mixture of equal parts kerosene and SAE 20 motor oil. Use the glaze breaker in a way that produces a cross-hatch finish on the liner bore. The cross-hatch pattern should be at an angle of approximately 30 degrees to the liner bore.

Clean liner walls thoroughly after deglazing. Wipe as much abrasive material from the wall as possible. Then, swab out liner with SAE 10 oil and carefully wipe it out with a clean cloth. One swabbing and wiping is not enough. Usually, three such operations are required and more may be necessary. Continue cleaning until a clean white cloth shows no evidence of discoloration in the liner bore. Never use gasoline, kerosene, or commercial cleaners to clean liners. Such solvents will not remove abrasives from liner walls. Failure to properly clean abrasives from walls can result in rapid engine wear and ring failure.

CRANKSHAFT INSPECTION AND SERVICE

The crankshaft used in diesel engines is a very strong and durable component, but it must be handled with care to avoid possible fractures or damage to the finished surfaces. While the crankshaft is out of the engine, clean it thoroughly with an appropriate solvent and have all of the oil passages blown out with compressed air. Also, check the oil seal surfaces for corrosion, varnish, or sludge deposits that could affect the ability of the seal to hold oil. Remove excess deposits that are not readily removed with solvent with crocus cloth. In the event that there is a burr on the oil seal surface of the crankshaft, it can also be removed by crocus cloth.

NOTE: Do not use the crocus cloth to the extent that seal surfaces become polished. A finely polished surface may produce poor sealing or cause premature seal wear.

Inspect the crankshaft bearing journals for cracks, scratches, grooves, or scores. Measure each journal in at least four places (Fig. 53) to determine diameter, out-of-round, taper, or undersize condition as shown in Figure 53. This measurement is performed with a micrometer.

A VS B = VERTICAL TAPER
C VS D = HORIZONTAL TAPER
A VS C AND B VS D = OUT-OF-ROUND
CHECK FOR OUT-OF-ROUND AT
EACH END OF JOURNAL

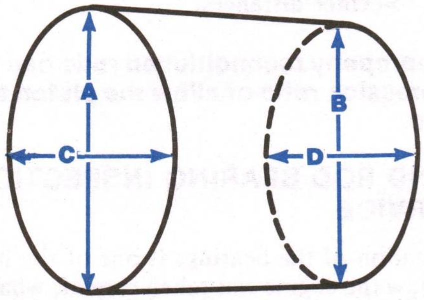


Figure 53. Crankshaft Journal Measurement

NOTE: A tapered crankshaft rod journal will affect the rod bearing as shown in Figure 54, and will also put undue pressure on the bearing, cylinder wall and piston causing excess wear or failure.

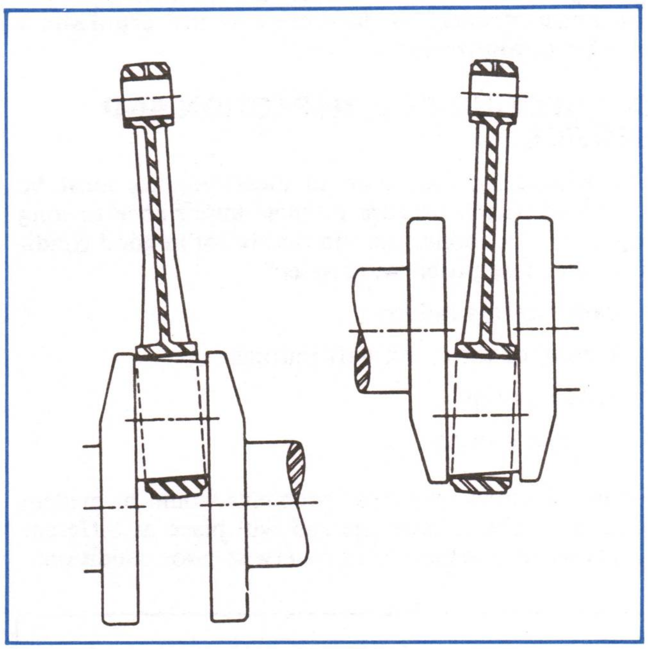


Figure 54. Effect of Tapered Crankshaft Journal

NOTE: In the event of a bearing failure, check the journal on which the bearing failed for hardness. This test is performed using the Rockwell Hardness Tester. Check the shop manual for instructions and minimum hardness specifications.

Besides checking the main and rod journals, inspect the crankshaft for straightness. This is done by setting the crankshaft in V-blocks on the two end journals and measuring the runout of the center journal with a dial indicator (Fig. 55).

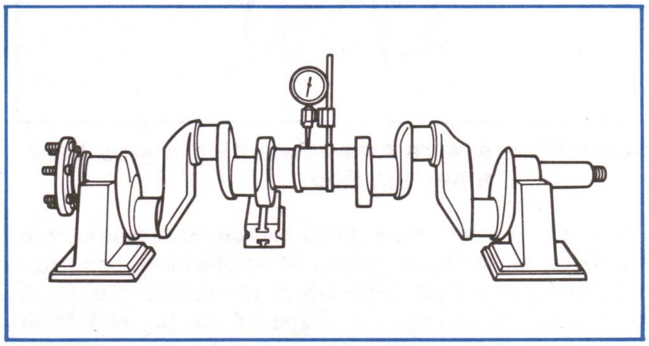


Figure 55. Checking Crankshaft for Straightness

SHORT BLOCK INSPECTION AND SERVICE

CAUTION: Many of the crankshafts used in diesel engines are induction hardened and must not be straightened. Even slight straightening with complete absence of cracks will endanger the high strength built into the shaft. Check the appropriate shop manual to determine if the crankshaft can be straightened.

CONNECTING ROD INSPECTION AND SERVICE

The connecting rods used in diesel engines must be closely inspected because of their importance to long engine life. A connecting rod that is not in good condition can cause problems such as:

- Early bearing failure
- Scoring of the crankshaft journals
- Piston scoring
- Cylinder scoring

Figure 56 shows why these problems would be evident because of the stresses the rod will place at different points when it is bent or in otherwise poor condition.

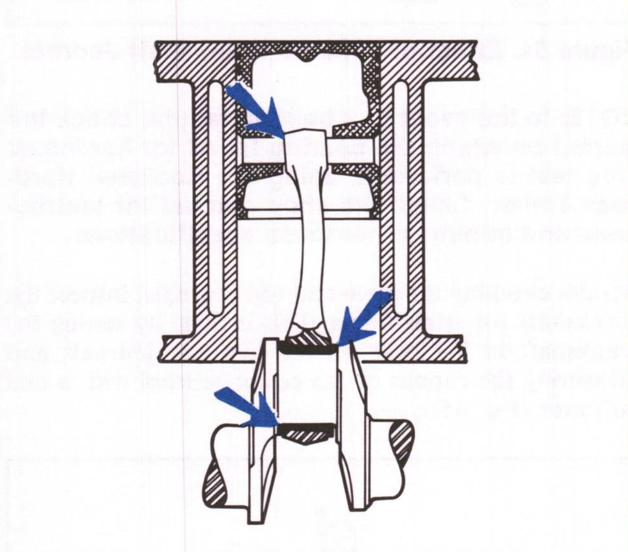
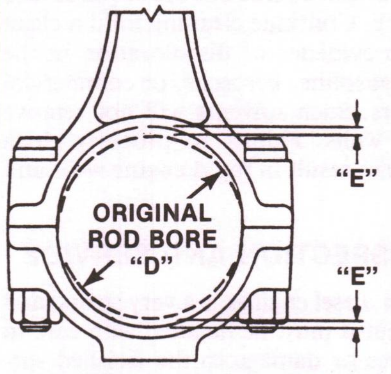


Figure 56. Pressure Areas Resulting from a Bent Connecting Rod

The need for checking a diesel rod closely results from distortion caused by the forces of combustion, compression, and centrifugal force which act on the rod. Such forces tend to change the shape of the big end from round to oval (Fig. 57), to twist and bend the rod and deform the shape of the piston pin bore.



NOTE: As the result of pressures, the large end of connecting rods becomes oval. "D" is the original bore and "E" is the amount of stretch at top and bottom.

Figure 57. High Mileage Rod Wear

There are several points that can be looked at to help determine the condition of a rod. They are:

1. Look for a shiny surface on the edge of the piston pin. This may indicate that a connecting rod is bent or the piston pin hole is not in proper relationship to the piston skirt and ring grooves.
2. Abnormal connecting rod bearing wear may be caused by either a bent connecting rod, an improperly machined journal, or a tapered rod bore.
3. A twisted connecting rod will not show an easily identified wear pattern on the cylinder wall. However, badly twisted rods disturb the action of the entire piston, rings, and connecting rod assembly which may be the cause of excessive oil consumption. In addition, the bent connecting rod may cause more cylinder taper than that found in neighboring cylinders.

In a high mileage rebuild, measure the rod bores carefully to determine if they are out-of-round or have excessive diameters. If there are problems, the rod can often be reconditioned by a competent machine shop and then be reused. While the rods are being reconditioned check for straightness and center-to-center distances.

NOTE: Improperly reconditioned rods can change the compression ratio or allow the piston to strike the valves.

MAIN AND ROD BEARING INSPECTION AND SERVICE

An examination of the bearings is one of the best indicators of how the engine was taken care of; what caused a failure (if there was one); and what the general condition of the crankshaft and rods is (if they are bent, tapered, etc.)

SHORT BLOCK INSPECTION AND SERVICE

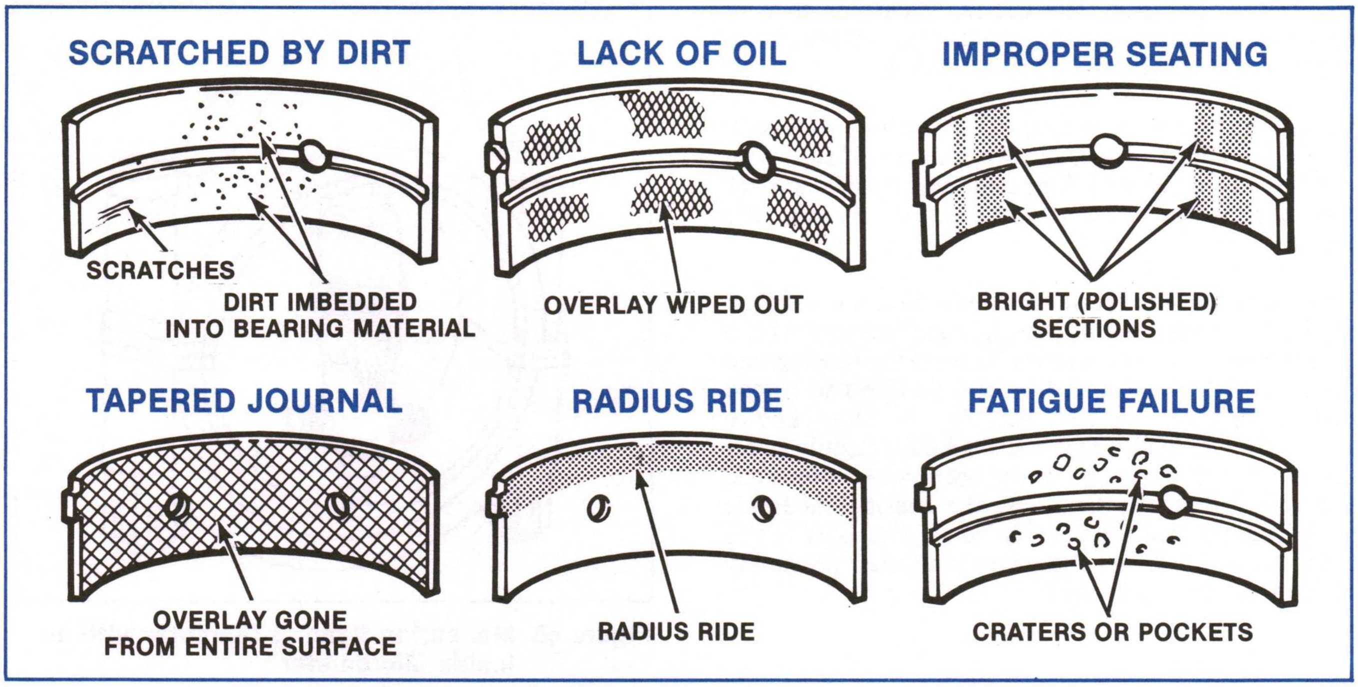

SCRATCHED BY DIRT
LACK OF OIL
IMPROPER SEATING
TAPERED JOURNAL
RADIUS RIDE
FATIGUE FAILURE
SCRATCHES
DIRT IMBEDDED INTO BEARING MATERIAL
OVERLAY WIPED OUT
BRIGHT (POLISHED) SECTIONS
OVERLAY GONE FROM ENTIRE SURFACE
RADIUS RIDE
CRATERS OR POCKETS

Figure 58. Types of Bearing Failure

During disassembly of the engine, it is very important to place the bearings in numerical order on the workbench. This will help in locating any trouble that may be present.

During inspection, examine the front and back surfaces of the bearing shell carefully, since the condition of the surface will reveal what has been happening with the bearing; what it has been exposed to; and if there was a failure, what caused it (Fig. 58). When looking at the back of the bearing, check to see that the tang is still there; if it is gone, the bearing has probably spun.

Bearing failures always have a cause. The major causes are listed here. The percentage of bearing failure due to a certain cause was determined by a major bearing manufacturer.

MAJOR CAUSES OF BEARING FAILURE

Dirt	43%
Lack of lubricant	15%
Misassembly	13%
Misalignment	10%
Overloading	9%
Corrosion	5%
Other	5%

These percentages, especially the top one, dirt—43 percent, should serve as an example of the importance cleanliness plays in overhauling a diesel engine.

Choosing Bearings

Bearings are usually standard and come in sets. Before replacing the bearings, be sure that the crankshaft does not have any undersize journals that need an oversize bearing. Oversize bearings are normally available for most engines.

Because of the precision machining in some diesel engines, there may be different size main and rod bearing thicknessess available for standard, first undersize and second undersize crankshafts. Essentially, this means that bearings in the block and main caps, or in the rod and rod cap can be purposely mismatched to take up any variations in the crankshaft journals. Usually, these bearings are color coded. Be sure that on engines which make use of bearings in this way that shop manual procedures are followed exactly.

Installing Bearings

When installing bearings, the first step is to clean the connecting rod or main bearing bore. Also, it is important to check the bore for size and circularity. Before installing the bearing shells, the bearing bores and shells must be wiped clean. The bearing shells can then be pressed into position, taking care that the oil holes in the shells match up with the oil supply holes.

Be sure the bearing is fully seated on the bore. If it isn't, there's something wrong somewhere. Also, if close contact is not made, there will be poor heat transfer and the excessive temperatures will shorten bearing life considerably.

To be sure that the bearing shell will have a close fit in the bearing bore, the bearing is manufactured with a slight spread, so it is necessary to force the bearing into the bore. The bearing shell is also designed to extend slightly beyond the bearing seat (Fig. 59). This is known as "crush." Actually, each bearing half is slightly larger than a full half circle. When the bearing cap is installed and torqued to specifications, the bearing shells are forced tightly into the bearing bores. Not only is this better for heat transfer, but there is also less possibility of the shell turning in the bore.

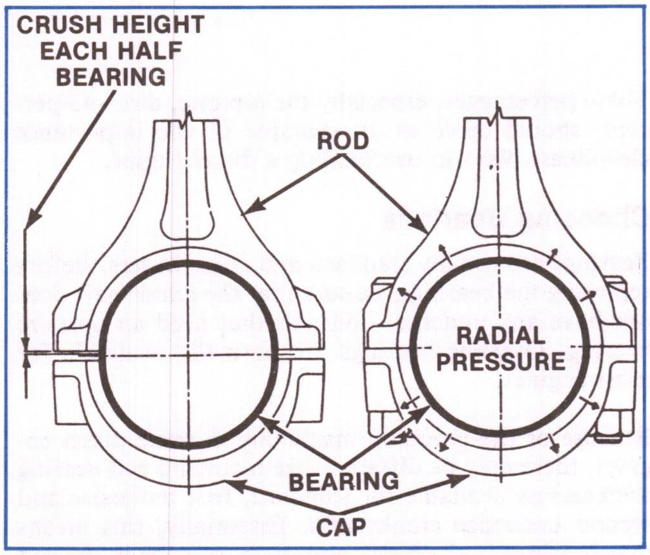


Figure 59. Effect of Bearing Crush

Checking Bearing Clearance

Check the bearing oil clearance. This can be done using the Plastigage method detailed earlier on Page 24. Also, it can be done by measuring the inside of the diameter of the bearings when they are torqued in place with an inside micrometer (Fig. 60). Then, compare the measurement with the diameter of the crankshaft journal.

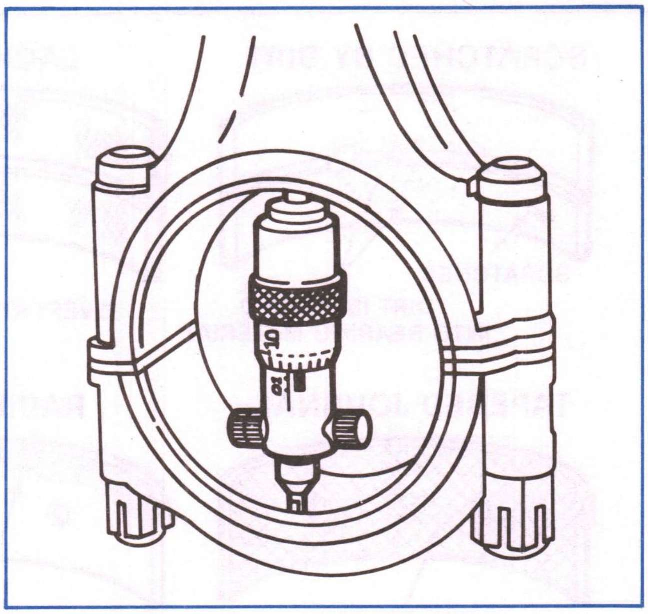


Figure 60. Measuring Bearing Diameter with an Inside Micrometer

GEAR TRAIN AND TIMING COMPONENT INSPECTION AND SERVICE

Diesel engines use a variety of drives:

- Belt (Fig. 61)
- Gear (Fig. 62)
- Chain (Fig. 63)

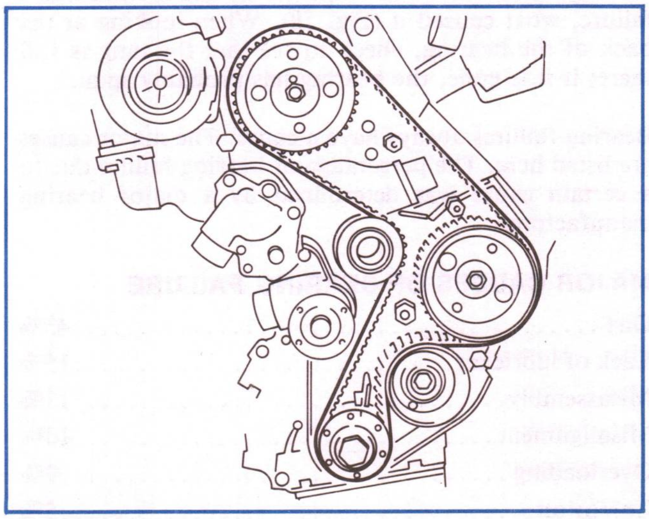


Figure 61. Belt Drive

SHORT BLOCK INSPECTION AND SERVICE

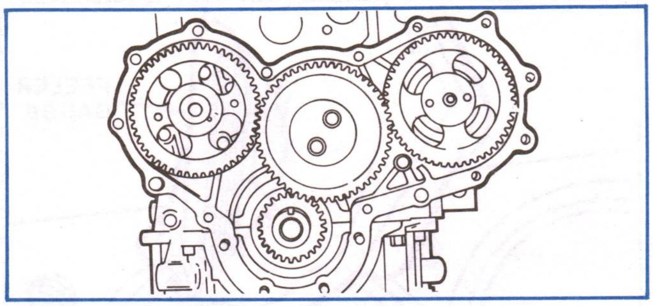


Figure 62. Gear Drive

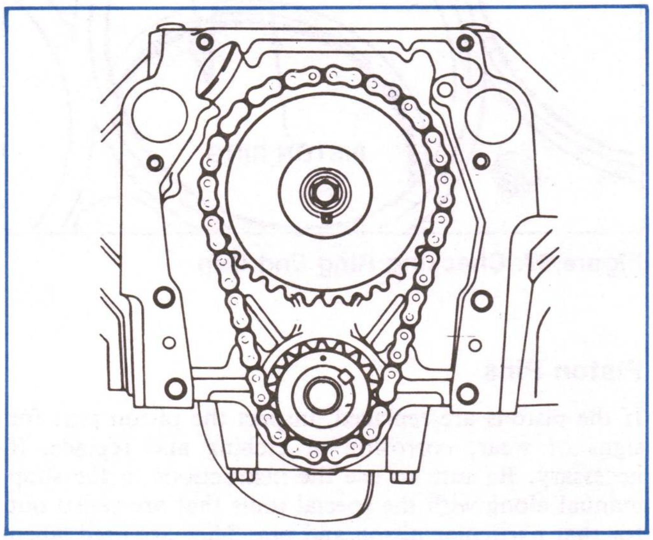


Figure 63. Chain Drive

NOTE: At the time of printing Ford Motor Company only used diesel engines with belt or gear drive.

Inspecting these components is a very important part of any engine rebuild. The shop manual contains information on these different drive systems and what to look for, especially on the gear drive system on which backlash and gear clearance are important checks.

PISTON INSPECTION AND SERVICE

Inspecting the pistons in a diesel is a very important aspect of overhauling a diesel engine, especially if they are going to be used again. Clean pistons that are to be reused. Then, check carefully for cracks, for good ring groove condition, and for good piston pin bores.

Measurements on the piston and rings are done in several locations. First, check the diameter of the piston with an outside micrometer at the center of the skirt at right angles to the piston pin bores (Fig. 64).

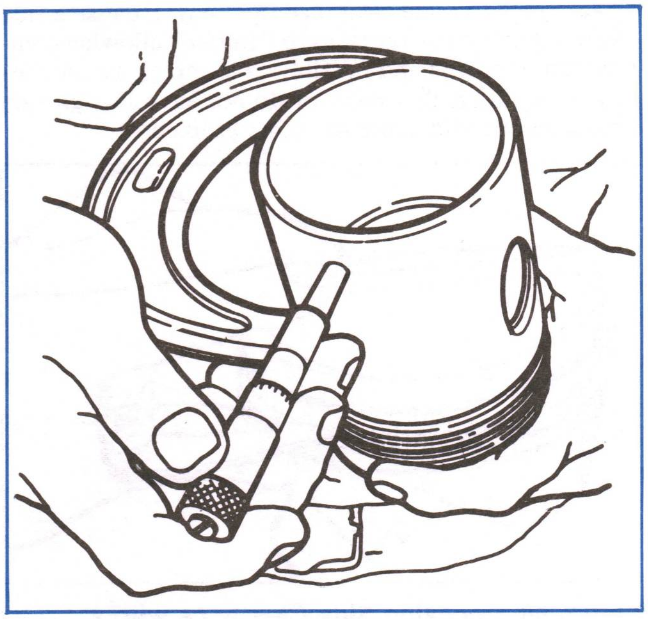


Figure 64. Measuring Piston Diameter

Determine the piston clearance in the cylinder by measuring the diameter of the bore and then the diameter of the piston with micrometers. The difference between the two measurements is the piston clearance. Another method is to insert a feeler gauge between the piston and the cylinder wall.

Clean the ring grooves using an appropriate ring groove cleaner (Fig. 65). Avoid removing any metal from the ring grooves.

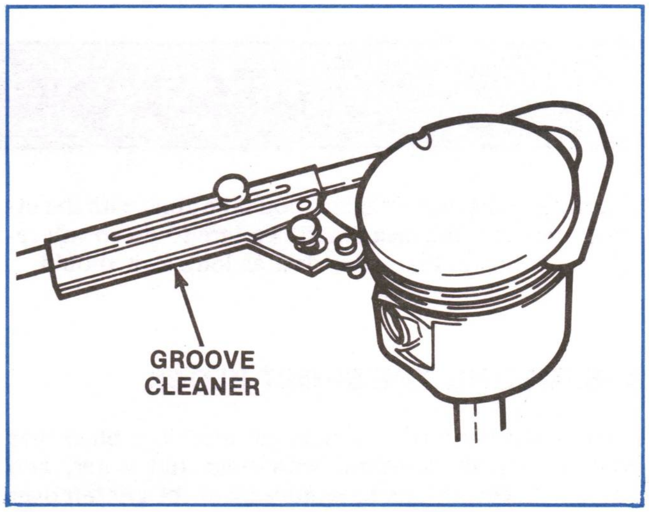


Figure 65. Ring Groove Cleaner

SHORT BLOCK INSPECTION AND SERVICE

Check rings for side clearance (Fig. 66). Excessive side clearance will allow the rings to "flutter" allowing compression to escape and possibly cause excessive oil consumption. Rings that bind, or do not have enough side clearance can also cause the same problems.

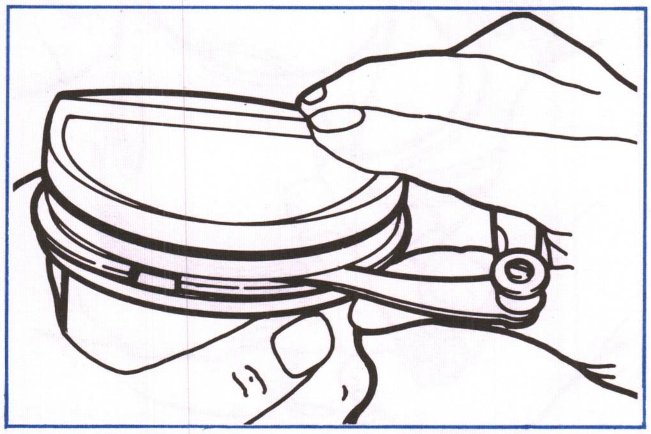


Figure 66. Checking Side Clearance with a Feeler Gauge

Check the ring end gap (Fig. 67) to ensure that when the engine warms up, the piston rings will not expand to the point where they touch. To make this measurement, place the piston ring in a cylinder and force it down with a piston so that it is straight in the cylinder. Measure the gap with an appropriate feeler gauge.

Installing Piston Rings

Install the piston rings on the piston using a ring expander since hand expansion of the rings tends to distort them.

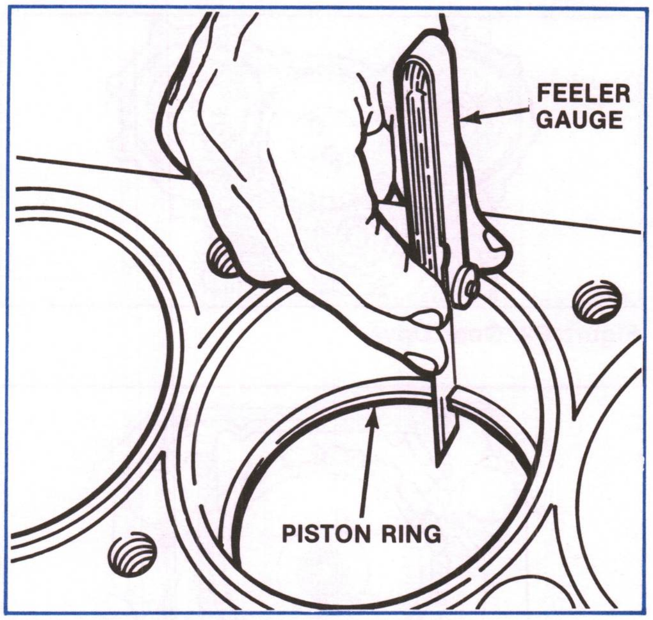


Figure 67. Checking Ring End Gap

Piston Pins

If the pistons are replaced, inspect the piston pins for signs of wear, corrosion or etching and replace, if necessary. Be sure to use the instructions in the shop manual along with the special tools that are called out for that particular piston and pin. They are used when pressing the pin in or out of the piston. Otherwise, the piston and/or pin could be distorted or destroyed during the removal and replacement procedures.

DIESEL ENGINE ASSEMBLY

Assembling the diesel engine should be done with the utmost precision and cleanliness. Failure to do so will result in an engine that won't last as long as it should.

ASSEMBLING THE SHORT BLOCK

Begin assembling the short block after the block has been thoroughly scrubbed with soap and water, and rinsed with clean water to remove all of the grit left over from honing. After the cylinder bores are washed, blow dry with compressed air. A good tool to use in a situation like this is a siphon/blow gun (Fig. 68). After the block is washed with soap and water, air and solvent can be sprayed on the bores to displace the water and prevent rusting. The solvent will also help to remove any remaining grime. Since the solvent evaporates quickly, it will not attract dust or other airborne contaminants. Finally, wipe the bores with a lint free cloth, and oil them down with the proper engine oil. See Page 35 for a description of the oil that should be used in diesel engines. A procedure like this must be used to prevent rust on the cylinder walls.

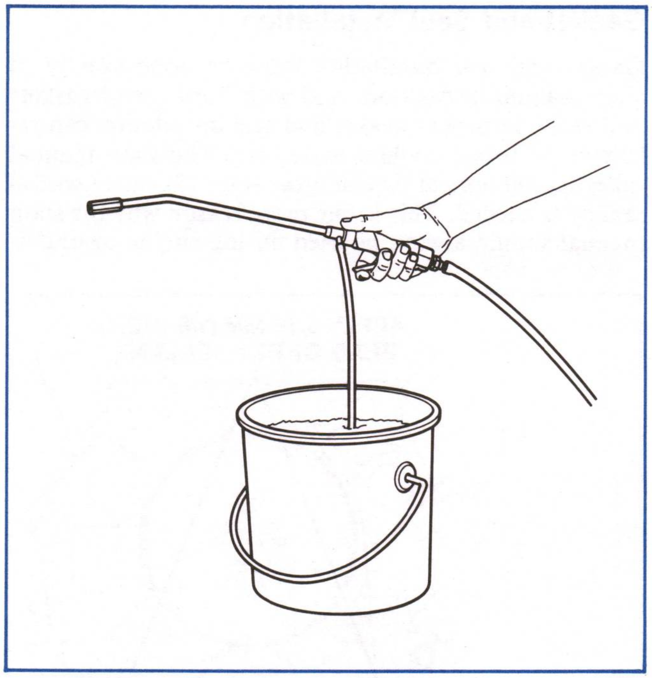


Figure 68. Siphon Blow Gun

After cleaning the cylinders, put the pistons into their respective cylinders. Be sure that the instructions for piston direction are followed in the shop manual since many of the pistons are directional. Also, be sure that the pistons are installed using a ring compressor (Fig. 69) to prevent damaging the rings.

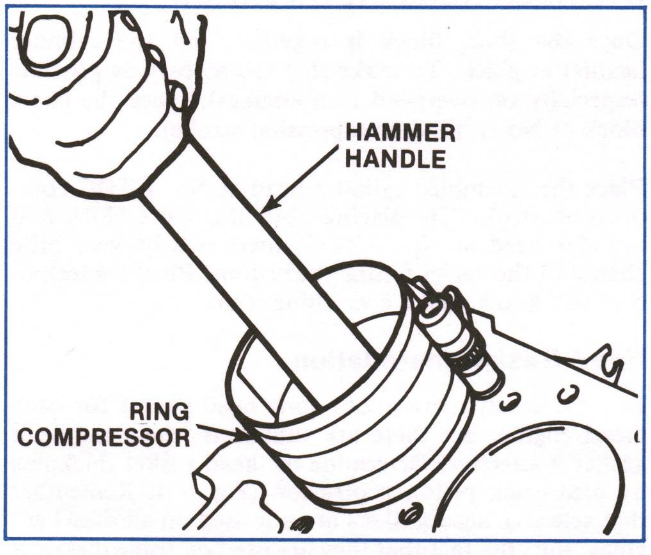


Figure 69. Installing a Piston in a Cylinder

Piston Cooling Jet Installation

After installing the pistons, put the piston cooling jets into position. This involves different procedures on different engines because some tubes are pressed in while others are bolted in. Piston cooling jets that are pressed in require a special tool (Fig. 70) to install them. Also, they must be aligned and aimed (Fig. 71). Failure to align and aim the piston cooling jets can result in rapid engine failure due to piston seizure.

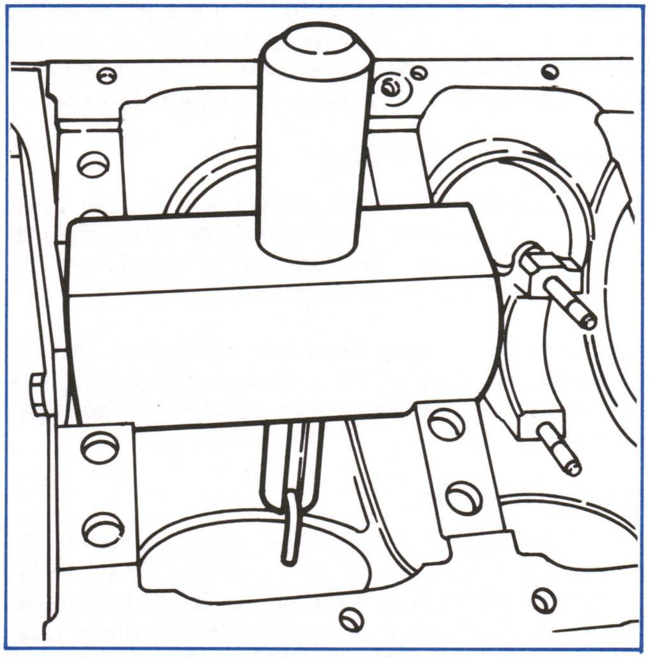


Figure 70. Piston Cooling Jet Installation

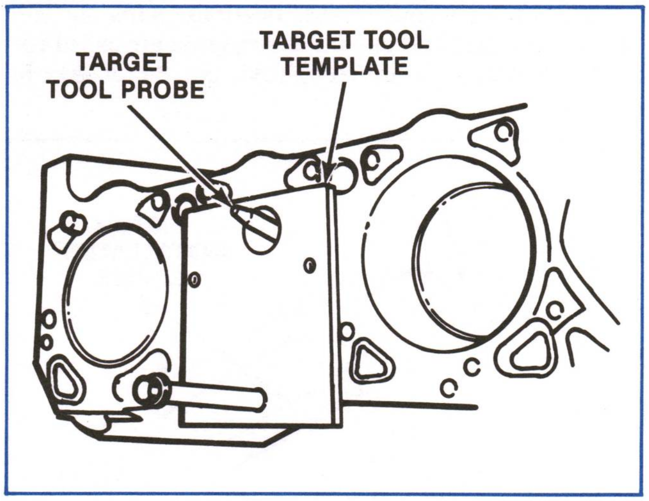


Figure 71. Piston Cooling Jet Alignment and Targeting Tools

NOTE: Some diesel engines require special tools for piston cooling jet installation and alignment. Check the shop manual for the required tools and correct procedure.

NOTE: Some pistons are not installed until the piston cooling jets and crankshaft are installed. Check the shop manual.

NOTE: Although piston cooling jets that are bolted in do not usually have alignment and targeting tools, it is still very important that care be taken in their installation. Damage to them could throw off the oil spray possibly causing engine damage.

Crankshaft Installation

After installing the piston cooling jets, set the main bearings in the saddles. Place the crankshaft carefully in the block. The main caps can then be installed on the block and torqued to specifications.

NOTE: Main bearing caps are numbered and directional. Be sure that the main bearing caps are put in the proper place and pointed in the right direction.

Rod Installation

Once the crankshaft is in position, attach the rods to the crankshaft. On some engines the pistons would be installed into the block at this time. At times, the installation of pistons requires special installation guides (Fig. 72). The purpose of the guides is to be sure that the piston cooling jets are not damaged by the rod bolts and that the crankshaft journal is not marred. Once the rods are in position, torque to specifications. After the rod bolts are torqued and any other steps that are called for by the shop manual are completed, put the oil pan in place.

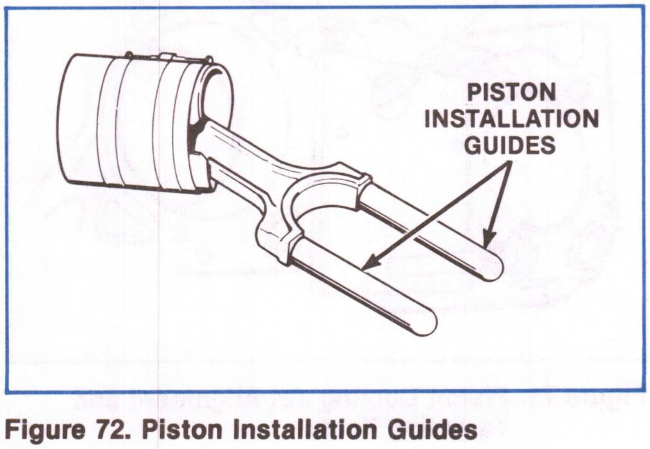


Figure 72. Piston Installation Guides

Gasket and Seal Installation

Gasket and seal installation must be done exactly to shop manual instructions and with Ford brand gaskets and seals. Improper gasket and seal installation can result in oil leaks, coolant leaks, etc. The shop manual takes special note in several areas (Fig. 73) where special sealing is needed. This is one more reason why the shop manual should always be used during engine overhaul.

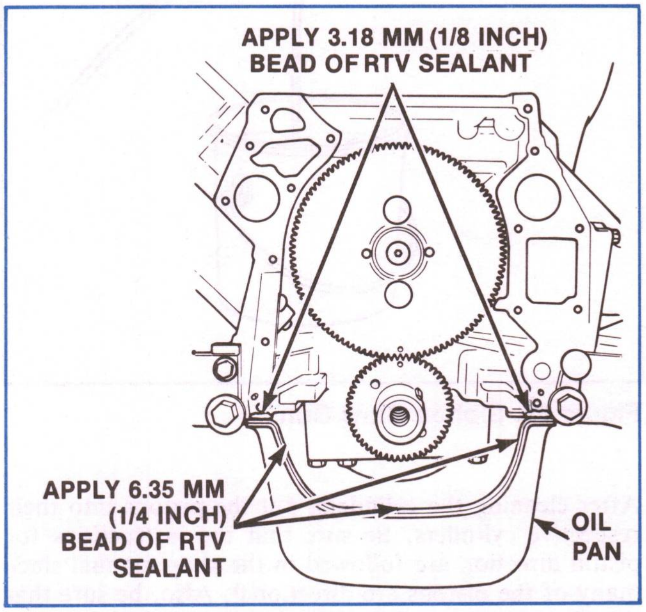


Figure 73. Examples of Special Gasket and Seal Instructions

CYLINDER HEAD INSTALLATION

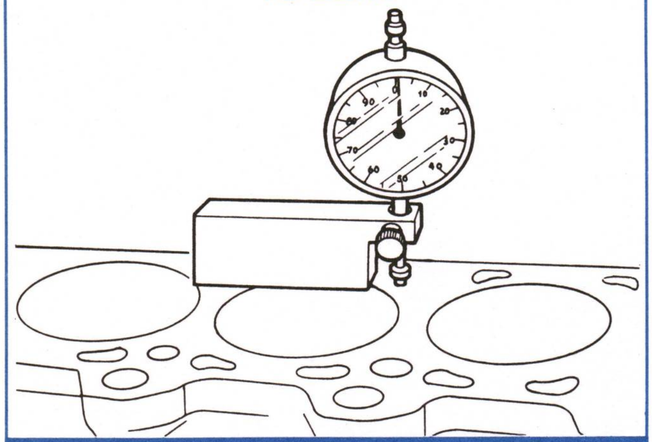
Once the short block is together, put the cylinder head(s) in place. To make this job as easy as possible (especially on overhead cam engines), place the short block at No. 1 TDC (compression stroke).

Place the assembled cylinder head at No. 1 TDC compression stroke. By placing both the short block and cylinder head at No. 1 TDC, there will be very little chance of the valves hitting the pistons. Plus, the technician will know where everything is at.

Head Gasket Installation

In most cases, there is only one head gasket for each diesel engine, but there are situations where the head gasket is selective. Determine the head gasket thickness by measuring piston protrusion (Fig. 74). Remember that selective head gaskets are not used on all diesel engines. But, the fact that they are used on some diesels is just another example of the precision in which diesel engines are manufactured.

SETTING DIAL INDICATOR TO ZERO



MEASURING PISTON PROTRUSION AT TWO POINTS

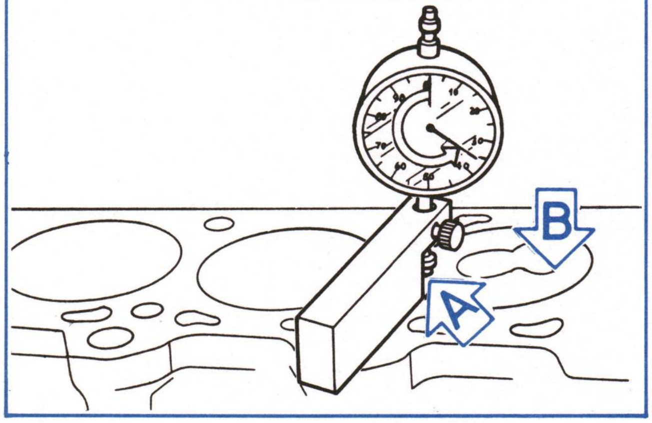


Figure 74. Measuring Piston Protrusion

Tightening the Cylinder Head

Once the head gasket is in place, put the cylinder head in the engine. Be sure that the head is at No. 1 TDC on the compression stroke and the short block is at TDC. Once the cylinder head is in place, bolt down the cylinder head according to shop manual procedures using the proper tightening sequence. Failure to use the proper tightening sequence can result in a warped or cracked cylinder head and a leaky head gasket.

Finishing Assembly

Once the block and cylinder head are together, complete the assembly of the engine by adding the timing components, vacuum pump, flywheel, fuel injection pump and all the other pieces that are attached to the engine.

NOTE: Do not remove the caps on the fuel system until the moment before attaching the components. This will lessen the possibility of dirt entering the fuel system.

Set the engine and fuel injection pump timing according to the shop manual procedures. Also, set the valve clearance according to the recommended procedures.

CHOOSING ENGINE OIL

The oil used in diesel engines should meet the manufacturer's recommendations that are placed in the Owner's Guide and in Ford service publications. This oil is different than the oil used in gasoline engines; it is tougher and meant to stand up to the extra stresses produced by the diesel engine. The API rating for this oil is usually SF/CC or SF/CD. The CC and CD indicate that the oil can be used in diesel engines. Determine the weight of the oil by the outside temperature using the graph (Fig. 75) in the Owner's Guide.

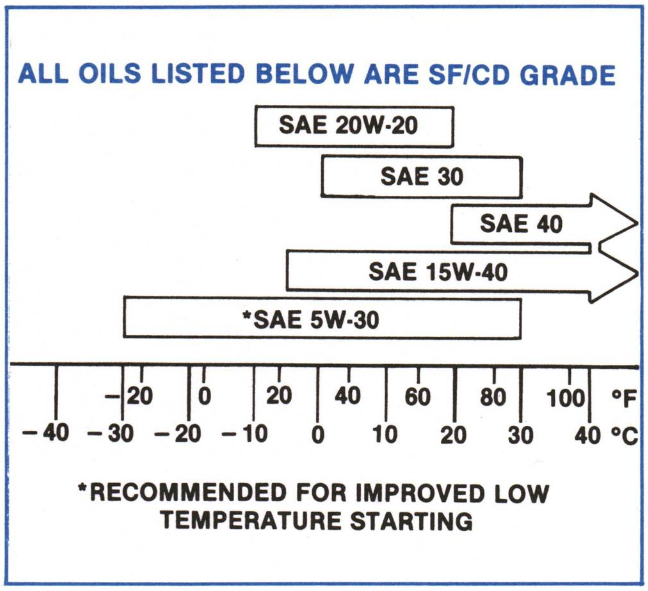


Figure 75. Example of Oil Weight vs. Temperature Graph

NOTES:

NOTES:

NOTES:

NOTES:

ASE CERTIFIED ™

WE SUPPORT VOLUNTARY TECHNICIAN CERTIFICATION

FPS-2202-006 Litho in U.S.A. March 1984